25,746/A

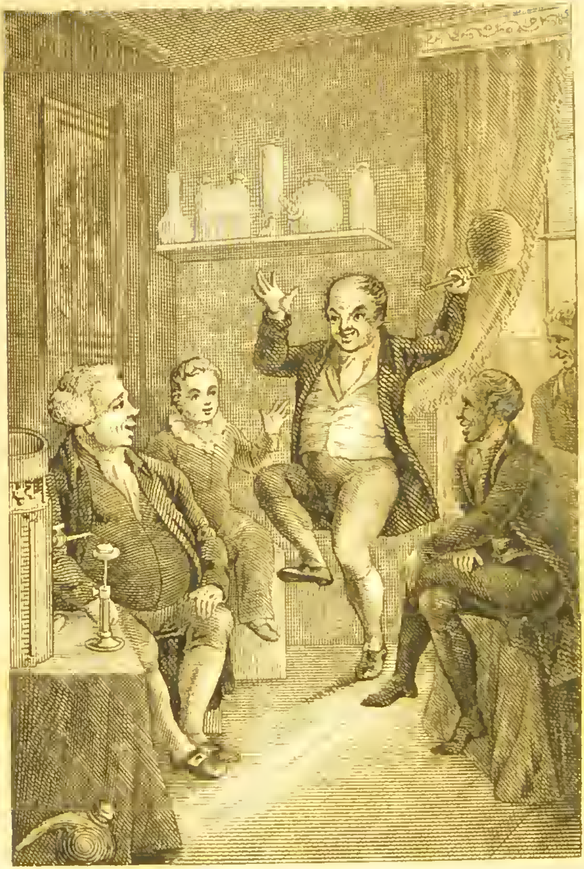
e M. Berkeley 36360

Dec. 1835

Digitized by the Internet Archive
in 2015

https://archive.org/details/b22021140

Chemical Recreations



Whimsical effects of Nitrous oxide Gas

36,360.

CHEMICAL RECREATIONS:

A SERIES OF
Amusing and Instructive Experiments,
WHICH MAY BE PERFORMED WITH
EASE, SAFETY, SUCCESS, AND ECONOMY.
TO WHICH IS ADDED,
THE ROMANCE OF CHEMISTRY,
AN INQUIRY
INTO THE FALLACIES OF THE PREVAILING THEORY OF CHEMISTRY,
WITH A NEW THEORY AND A NEW NOMENCLATURE.

BY JOHN JOSEPH GRIFFIN.

SEVENTH EDITION.
ENTIRELY REWRITTEN AND ILLUSTRATED BY NUMEROUS WOOD-CUTS.

GLASGOW:
PRINTED FOR R. GRIFFIN & CO., BUCHANAN ST.,
AND THOMAS TEGG & SON, LONDON.

1834.

WELLCOME
HISTORICAL
MEDICAL
LIBRARY

GLASGOW:
PRINTED BY GEORGE BROOKMAN

PREFACE.

A LITTLE book like the present has no title to a long preface. A few words will explain its plan and tendency.

It exhibits a condensed account of the nature and objects of chemistry, and of the methods by which it is taught and learnt.

It contains a description of the handiest methods of making chemical experiments on a small scale, for self-instruction.

It embraces an account of the properties of the elementary bodies, and of the most important of the compounds originated by their combinations.

It contains a series of several hundred choice experiments, calculated to display the remarkable properties of particular substances, and the general nature of chemical phenomena. These experiments will be found as amusing in performance, as instructive in their results. They are such as can be executed with little cost and without difficulty.

Lastly, it unfolds the principles of theoretical chemistry, examines the groundwork and superstructure of the prevailing system, points out its defects and the confusion to which the defects give rise, suggests a remedy, and presents a Nomenclature, a System of Arrangement, and a Theory of Combination, founded upon new principles.

Such is the plan, and such the tendency of this volume. It has the fault of taking perhaps too wide a circuit, and of bringing together subjects adapted for students of a different status; but I have been induced to adopt this course by a desire that my readers should be taught to *think* as well as to *experiment*, and thus be qualified at an early part of their study to discriminate between the true and the false, and acquire the facts of the science without being mystified by its fictions.

The critic who may incline to censoriousness, is reminded that the task I have undertaken is no easy one. To reform the nomenclature of chemistry, is to cleanse the Augean stable, where rubbish has been accumulating for forty years.

Glasgow, June 1st, 1831.

CONTENTS.

INTRODUCTION.

Nature and Benefits of Chemistry . . page ix
Objects of Chemical Experiments . . xii
Various kinds of Chemical Experiments . xiii
Different sorts of Chemical Substances . . xviii
On the cause of Chemical Combination . . xviii
Fallacies of Doctrinal Chemistry . . . xxi

CHEMICAL MANIPULATION.

The Laboratory . page 1
Weighing . . 3
Measuring . . 5
Pulverisation . 6
Solution . . 8
Supports . . 13
Lixiviation . . 15
Evaporation . 15
Distillation . 17
Sublimation . 21
Crystallisation . 21
Neutralisation . 23
Testing . . 24
Decantation . 25
Filtration . . 27
Precipitation . page 29
Edulcoration . 31
Solution of Precipitates 33
Ignition . . 33
Fusion . . 35
Reduction . . 35
Application of Heat 36
Use of the Blowpipe 40
Management of Gases 45
Compound Distillation 54
Lutes . . . 57
Instructions for fitting up a small Laboratory, with list of Apparatus and Preparations . 58

CHARACTERS OF CHEMICAL BODIES.

Oxygen . . . page 68
Sulphur . . . 70
Nitrogen . . . 72
Chlorine . . . 75
Bromine . . . 77
Iodine . . . 78
Fluorine . . . 78
Phosphorus . . . 79
Selenium . . . 80
Arsenic . . . 80
Chromium . . . 81
Vanadium . . . 82
Molybdenum . . . 82
Tungsten . . . 82
Boron . . . 83
Carbon . . . 83
Antimony . . . 88
Tellurium . . . 89
Tantalum . . . 89
Titanium . . . 90
Silicium . . . 90
Hydrogen . . . 90
  Acids . . . 93
  Salts . . . 93
  Hydrates . . . 94
  Oxygen Salts . . 95
  Silicates . . . 109
  Organic Compounds 111
  Vegetable Chemistry 115
  Animal Chemistry 127
Osmium . . . 128
Gold . . . 128
Iridium . . . page 130
Rhodium . . . 130
Platinum . . . 130
Palladium . . . 131
Mercury . . . 133
Silver . . . 134
Copper . . . 135
Uranium . . . 139
Bismuth . . . 139
Tin . . . 140
Lead . . . 141
Cerium . . . 143
Cobalt . . . 144
Nickel . . . 145
Iron . . . 145
Cadmium . . . 149
Zinc . . . 149
Manganese . . . 151
Thorium . . . 152
Zirconium . . . 152
Aluminum . . . 152
Yttrium . . . 154
Glucinum . . . 154
Magnesium . . . 155
Ammonium . . . 156
Calcium . . . 160
Strontium . . . 164
Barium . . . 165
Lithium . . . 16
Sodium . . . 16
Potassium . . . 17

THE ROMANCE OF CHEMISTRY.

Defects of the prevailing Nomenclature . . page 186
Defects of the prevailing Theory of Chemistry . 189
Requisites of a Chemical Theory . . 194
Table of the Elements, and of the Weights, Symbols, and Names of their Atoms 194

Definitions of Important Terms:—

Element 196
Compound 196
Atom 196
Atomic Weight 199
Atomic Weight of a Compound . . 200
Volume 200
Atomic Measure 200
Symbol of an Atom . . . 200
Name of an Atom . . . 201
Positive and Negative . . . 201
Phenomena of Chemical Combination and Decomposition 201
Theory of Combination 204
Limits of Combination 205
Application of the Corpuscular Theory to Chemistry 214
Determination of the Atomic Weights of the Elements 222
Rules for applying Symbols to denote the Atomic Constitution of Chemical Compounds . . . 232
Rules for forming Names to denote the Atomic Constitution of Chemical Compounds . . . 234
Effect of New Discoveries upon this Nomenclature 239
Proximate and Ultimate Constitution . . 242
A Chemical System 245

AMUSING EXPERIMENTS.

Chemical Metamorphoses . . . page 275
Experiments on Heat and Cold . . . 287
Illustrations of Galvanism . . . 301
Experiments producing Combustion, Explosion, and Light 306
Amusing Experiments with Gases . . 320
  Oxygen Gas 321
  Hydrogen Gas 325
  Carbonic Acid Gas . . . 330
  Nitrogen Gas 331
  Nitrous Gas 332
  Nitrous Oxide Gas . . . 332
  Chlorine Gas 333
  Muriatic Acid Gas . . . 334
  Olefiant Gas 335
  Sulphuretted Hydrogen Gas . . 335
  Sulphurous Acid Gas . . . 336
  Ammonia Gas 336
  Fluoboric Acid Gas . . . 337
  Iodine Vapour 337
Illustrations of Chemical Arts . . . 337
  Ink-making 337
  Colour-making 339
  Dyeing 341
  Calico Printing 345
  Bleaching 346
  Metallic Arts 348
  Domestic Economy, Perfumery, &c. . 350
Chemical Curiosities 355
Chemical Tests 368

INTRODUCTION.

CHEMISTRY is the science which makes known to us the properties of the component particles of all natural bodies. I speak not only of those *compound* particles which are the result of organisation, but of the ultimate, indivisible, or *elementary* particles. It treats of the infinitely various *sorts* of substances, and of the exact determination of their differences. It exhibits the means by which the component parts of compound bodies can be separated from one another, or by which the elements of compounds can be made to combine together. In fine, it shows by what contrivances the corpuscles which constitute the world, can be most beneficially applied to the service of man.

The objects of chemistry are inexhaustible. It undertakes the examination of all substances which act upon the senses. It seeks to determine the properties of those substances, the number and proportion of their component particles, the individual nature of those components, and the properties of all other compounds which can be produced by their combination, either in different numbers or in different proportions. There are no bounds to the researches of chemistry; because, at whatever point its operations commence, there is no telling to what they may lead. Indeed, so infinitely varied are its objects, that it is an everlasting source of occupation and amusement; and while, on this account, it receives the attention of the curious philosopher, it claims the notice of all men, from its utility in the arts by which the comforts and existence of civilized life are promoted and supported.

The great importance of the science of Chemistry is rendered evident by the following considerations.—It is useful in explaining natural phenomena; and, in acquiring a knowledge of the constitution of the atmosphere, in investigating the changes to which it is subject, the variations of temperature, the laws of winds, dew, rain, hail, and snow, Chemistry is our principal, our only satisfactory guide. These remarkable changes in the face of nature—changes which, because familiar, do not produce any emotion in the mind, though in themselves truly wonderful—are chemical operations on a magnificent scale, and can only be explained by chemical laws.

In man's researches into the nature of the things whence he derives the means of his comfort, his happiness, his luxuries, and even his existence—in examining the various objects which compose the mineral, the vegetable, and the animal kingdoms, Chemistry is essentially requisite for the successful progress of his inquiries.

In considering the application of Chemistry to the improvement of the arts of civilized life, a wide field of contemplation opens to our view. So extensive, indeed, are its influence and importance, that, in most of the arts, many of the processes—in some all that are employed, depend on chemical principles. The bare mention of some of these arts will suggest ample illustrations of its extensive utility.

In the medical art, of so great service is a knowledge of Chemistry, that it is now universally regarded as an essential branch of a medical education. In the art of extracting metals from their ores, in purifying and combining them with each other, and in forming instruments and metals—whether for useful or ornamental purposes—almost all the processes are purely chemical. The arts of glass and porcelain making, of tanning, soapmaking, dyeing, and bleaching, depend entirely upon chemistry; and all the processes in baking, brewing, and distilling, most of the culinary arts, and many other processes in domestic economy, are chemical operations. In short, wherever, in any of the processes of nature or of art, the accumulation or the diminution of heat takes place—wherever substances in combination are to be separated—wherever the union of simple substances and the formation of new compounds are effected;—the operations and their results can only be explained on chemical principles.

From this general view of the extensive application of chemical science, those who have not considered the objects which it embraces will be enabled to judge of the importance of this study.

If we consider Chemistry purely as a science, we shall find no study better calculated to encourage that generous love of truth which confers dignity and superiority on those who successfully pursue it. There is no science which holds out more interesting subjects of research, and none which affords more striking proofs of the wisdom and beneficence of the Creator of the universe. A machine constructed by human art, is admired in proportion to the simplicity of its contrivance, to the extent of its usefulness, and to the niceness of its adaptations. But the works of man sink into nothing when brought into comparison with the works of nature. When we examine the former, every step of our progress is obscured with comparative clumsiness and defect: in contemplating the latter, we behold perfection rise on perfection, and more exquisite wonders still meeting our view. It is the merit of Chemistry, that by its aid we are enabled to take a minuter survey of the great system of the universe. And we find, so far as our limited powers can comprehend it, that the whole is nicely balanced and adjusted, and that all its changes tend to the most beneficial purposes. Circumstances which, on a superficial view, were seeming imperfections and defects, a closer inspection points out to be real excellencies. In all the singular and surprising changes which everywhere present themselves, the more closely we observe and examine them, the more we admire the simple means by which they are accomplished, and the intelligent design and perfect wisdom displayed in the beneficial ends to which they are directed.

Chemistry is a science that is founded entirely upon experiment; and no person can understand it unless he performs such experiments as verify its fundamental truths. The hearing of lectures, and the reading of books, will never benefit him who attends to nothing else; for Chemistry can only be studied to advantage *practically*. *One experiment*, well-conducted, and carefully observed by the student, from first to last, will afford more knowledge than the mere perusal of a whole volume. It may be added to this, that chemical operations are, in general, the most interesting that can possibly be devised.—Reader! what more is requisite to induce you to *make experiments?*

It has been demonstrated by the experiments of chemists, that the marvellous diversity of appearance under which bodies are presented to the eye, and the unceasing changes to which they are subject, are occasioned by the mutual reactions of a small number of unchangeable elementary particles. The properties of these particles, their weight, the nature of the phenomena which mark their action, the methods of causing them to combine, the properties of the resulting compounds, and the methods of decomposing these compounds, are consequently the objects which the chemical student is called upon to investigate.

There are two methods of proceeding in the acquisition of chemical knowledge; these are called *analysis* and *synthesis*. ANALYSIS means the art of *separating* the constituents of compound bodies,—SYNTHESIS, the art of forming compounds, by the *putting together*, or effecting the *combination*, of their component particles. Both analysis and synthesis are practically effected by the performing of certain processes or operations, thence called *chemical operations*.

The properties of natural bodies, whether they be simple or compound, native or factitious, can never be determined *à priori;* they can be discovered only by *actual trial*. When an unknown substance is presented to a chemist for examination, he submits it to certain *trials*, or performs certain *operations* upon it. He examines, for example, the relation of the unknown body to heat, light, water, acids, alcalies, and other liquids. These *trials* have particular *names* given to them, for the sake of convenience in the communication of knowledge. If a substance is exposed to a *red heat*, the operation is termed IGNITION. If the substance *melts*, the operation is termed FUSION. If the substance, on being put into water, *dissolves* or *disappears*, the operation is termed SOLUTION, and sometimes *dissolution*, and the resulting liquid is called *a solution*. If the solution is exposed to heat so as to cause the water to rise *in vapour*, the operation is termed EVAPORATION; or if the operation is so performed that the vapour is collected and reconverted into water, the operation is termed DISTILLATION. If, on the contrary, the solution, instead of being exposed to evaporation, is mixed with some liquid which causes the production of a *solid substance* or powder, the operation is called PRECIPITATION; and if means be taken to separate the solid powder from the residual liquid, by straining through a porous substance, this operation is termed FILTRATION.

The performance of these operations communicates to the chemist a certain degree of knowledge respecting the properties of the substance operated upon. If the substance does not melt when exposed to a strong degree of heat, it is said to be *infusible.* If it does not dissolve when placed in a liquid, it is said to be *insoluble.* No chemist can go farther than the ascertainment of simple facts. The sagacity of man is insufficient to determine WHY a given substance is soluble or insoluble, fusible or infusible. The *nature of the power* which causes fusion or solubility, is unknown. And, indeed, this is the case with regard to all physical phenomena, *the forces which produce them are unknown to man, except by their effects.*

The more numerous the operations performed upon a substance, the more knowledge is acquired respecting its properties; it being admitted that the operations are properly conducted. The properties of a substance can never be wholly known. Chemists begin with a single fact; their daily experience enlarges their knowledge: but, at the best, their acquaintance with the properties of any one body is but limited and imperfect. Not until a substance shall have been submitted to the action of every other substance, and under all possible variations of temperature, pressure, and so forth, will its properties be wholly determined; and that will *never be.*

The first business of a young chemist is to make himself acquainted with what is already known, with what has been already determined by the experiments of others. His next concern, to learn something which no one else has yet discovered. To this end, he must read books, make experiments, compare, reason, and judge.

Chemical experiments may be divided, for convenience, into three sorts; namely, Determinative, Demonstrative, and Productive.

(*a*) *Determinative.*—If any body brings me a substance, and desires to know the nature of it, I must make a *determinative experiment;* in other words, I must submit it to analysis, or *determine* by *experiment*, what it is composed of. Chemical analysis is of two sorts, qualitative and quantitative. A qualitative analysis makes known the chemical nature of the constituents of a compound, but not the relative quantities of those constituents. A quantitative analysis makes known both the nature of the constituents and the exact quantity of each by weight. Experiments of this sort are also called experiments of *research.* No man can execute an analysis without previously acquiring a considerable share of chemical information. Before a qualitative analysis can be executed, it is necessary to become acquainted with the properties of all the known elements and their principal compounds, as well as with the methods of determining whether any of them, on a certain occasion, be present or absent. The use of chemical *tests* or *reagents,* depends upon the knowledge previously acquired, that particular bodies, in particular circumstances, act in a determinate manner. There is a liquid called oil vitriol. I know that other liquids which contain certain substances in solution, upon being mixed with oil of vitriol, produce a precipitate. If, then, upon dissolving an unknown substance in water, and mixing the solution with oil of vitriol, I obtain no precipitate, I am certified that the substances alluded to are not present. It is evident, that unless I know beforehand what substances *do* give a precipitate with oil of vitriol, and what substances *do not*, it is useless to apply the test; because whether I see a precipitate or not, I acquire no information. A vast number of other substances serve, as well as oil of vitriol, the office of chemical tests, and their employment in chemical analysis constitutes a very important part of chemical study.

In quantitative analysis, something more has to be done. Supposing a man to know how to detect all the ingredients of a compound, supposing that he has detected them, he has, in quantitative analysis, the additional task of separating these ingredients from one another, and of determining their respective weights. In some cases, two substances can be separated from each other with ease; in other cases. the separation cannot be effected without great difficulty. The methods of separation depend altogether upon the properties of the particular substances which are to be separated, and can only be learnt by studying these properties. But much also depends upon the skill of the operator in the performance of the numerous operations which occur in analysis. The fusions, solutions, filtrations, and evaporations require to be performed with extraordinary care. If a drop of liquid falls down, or an atom of powder is blown away, the whole experiment is spoiled, and the labour probably of weeks may be frustrated. To perform an analysis with accuracy, should be the object of a student's ambition, but if he wishes to attain this object, he must not only industriously study the properties of chemical bodies, but continually accustom himself to manipulation, that he may become dexterous in the performance of those operations upon which the success of an analysis mainly depend.

(*b*). *Demonstrative Experiments* are of a different kind. They are employed in the *communication* of chemical knowledge. When a chemist has discovered any thing new, he announces the discovery, and describes an experiment by which the truth of his statement can be proved. This is a demonstrative experiment. There are certain substances which if heated at one end, very soon become hot at the other end; these are said to be *good conductors of heat.* There are other substances which on being heated at one end, are a long time before they become hot at the other end; such substances are called *bad conductors of heat.* A man discovers and states that the metal called platinum is a bad conductor of heat. The proof of this is easy. You take a short wire of platinum, hold it by the fingers at one end and place the other end in the flame of a lamp. You find that the heat comes to the fingers very slowly. This is a demonstrative experiment. As the students of a science are supposed to be quite ignorant thereof, it is the business of teachers to demonstrate the truth of their assertions by experiments, and accordingly lecturers on chemistry exhibit a great number of experiments. It would be in vain, however, to attempt to demonstrate everything. Want of time forbids it. But a teacher should be careful not to give as a chemical *fact*, what is *incapable of proof* by a chemical *experiment*. This, however, is a rule which every lecturer makes a point of disregarding, and extravagant theories are flung out with a most reckless and prodigal hand. On this account, I caution all students against receiving dogmas as facts, and accepting assertion for argument. I know of no chemist upon whose judgment I would found my belief. In an experimental science, where truth lies within a man's own reach, every person must make use of his senses and judge for himself. Those who are too ready to adopt as their own the opinions of another, are very liable to be deceived. It is astonishing to observe the number of false theories which have been propagated by the credulity of idle chemists. Our chemical books contain ten thousand assertions respecting the proximate constitution of bodies, of which *not one* is capable of proof. In studying chemistry, therefore, the student should look attentively to the *demonstrative experiments.* No one who is in the habit of reasoning upon what he hears, and believing only what is proved, will ever run the risk of talking absurdities about the properties of *dry nitric acid*, and other chimerical compounds, which nowhere exist but in the excited imaginations of over-credulous "philosophers."

(*c*). *Productive Experiments.* I have given this name to those experiments which have for object the *production* of chemical substances. The *Pharmacopeia* is a collection of productive experiments, containing neither more nor less than instructions for preparing or producing the chemical substances employed in medicine. It will be understood, of course, that many analytical and demonstrative experiments, are also productive experiments; but I understand by the latter term, those experiments only which are made for the express purpose of producing chemical preparations in quantities for use. Productive experiments form an admirable exercise for young students. The preparation of the various acids, oxides, salts, &c., is capable of furnishing most useful information respecting the properties of those substances, and has the further beneficial effect of habituating the student to careful manipulation.

The chemical properties of a substance characterise equally the smallest portion of that substance, or the greatest mass. That which can be demonstrated of a pound, can also be demonstrated of a grain. Hence chemical experiments may be performed, either with large portions of matter, or with small portions; and whether in any case a large or small portion should be operated upon, is a thing to be determined solely by expediency. In trade, where productive experiments are made with a view to obtain preparations for sale, the quantities operated upon are often extremely large, amounting to many tons in weight. In analysis, the quantity of a body submitted to a test weighs sometimes but the fraction of a grain. When a lecturer has to teach chemistry to a large audience, it is his duty to make his demonstrative experiments upon rather a large scale, otherwise a majority of the persons present may not be able to perceive what takes place. And whenever a theory is built upon a single experiment, the lecturer should take particular care to make this experiment in such a manner that every person present may see and comprehend it fully; for if the demonstration is not made to *tell*, the theory sinks unheeded, and the arguments grounded upon it are fustian. I give this hint to the Members of Mechanics Institutions, who have lately adopted the useful practice of lecturing to one another.

As the demonstrative experiments of the lecture room are unavoidably scanty and unsatisfactory, the student who desires to know somewhat more of the science than he can learn there, must necessarily pursue his studies at home. I recommend him to be very cautious in believing the dogmas he hears and reads, without seeing the experiments which are intended to verify them. It is indispensably necessary, that he perform with his own hands the fundamental experiments of chemistry, in the best manner his time, his apparatus, and his means will admit of. He will find it of importance in this case to operate upon extremely small portions of matter; for he will then not only save time and money, but often be enabled to perform a successful experiment, where, by operating upon a large mass, he would as certainly fail. The preparation of the gases, the formation and crystallisation of salts, the application of tests, and a thousand other entertaining and instructive experiments can all be performed by the student, better on a small scale than in the large way; nay more, a student in his closet very frequently succeeds in performing an experiment which fails on the lecture table of the professor; for the accidents which attend the hurry and business of a lecture room produce unavoidable disappointment. This therefore is a circumstance of which the chemical student should be prepared to take every advantage. The faculty of experimenting with accuracy, facility, and economy, ought to be gained as speedily as possible; for it is upon that faculty that the progress of the young chemist is principally dependant.

All natural bodies are either *simple* or *compound*. Those substances are SIMPLE, which cannot by any known method, be separated, decomposed, or divided, in such a manner as to produce particles different in their properties from one another, or from the original substances. On the other hand, those substances are COMPOUND, which experiment is capable of resolving into particles of an unlike nature. For a period of many centuries, and even till a very late date, there were four substances held to be simple or elementary. These were fire, air, earth, and water. Of these four bodies, all others were supposed to be constituted, though nobody could ever prove, or indeed ever tried to prove, that this was the case. The system, however, continued to be orthodox until very lately, when three of these imaginary *elements*, namely, air, water, and earth were proved to be compounds. But with respect to fire, it is still unknown whether it be simple or compound, or in what its essence consists, or by what causes its effects are produced. What the ancients considered to be simple bodies are no longer considered to be such; but in place of these substances, the chemists of modern times have elevated to the dignity of elements a far more numerous race. No one, however, dogmatically asserts now a-days that the substances termed elements are absolutely of a simple nature. The term element intimates no more than that the body to which it is applied, has never in the opinion of modern chemists been subjected to decomposition.

The number of elements is at present assumed to be fifty-four. The properties of these elements, and the experiments by which the separate identity of each is demonstrated, will be described in a subsequent part of this volume.

When the elementary bodies are placed in contact under particular circumstances, they unite or combine together, and produce compound bodies. Some combinations are effected very readily, and some with great difficulty, and there are certain elements which can scarcely by any means be made to combine. The compounds thus produced, possess properties very different from those of the elements of which they are composed. The POWER, in virtue of which simple bodies can combine and produce compounds, is one of which the nature is totally unknown to man. Chemists have learnt no more than that simple bodies, or bodies supposed to be simple, DO COMBINE; but WHY they combine, or *what it is* which MAKES THEM combine, they have not discovered. Very frequently, however, the act of combining is attributed to a particular occult power or principle, which is called *Affinity*. If you ask some chemists to tell you *why* bodies combine together, they will say, *because those bodies have an affinity for one another*. But if, on the other hand, you ask the same chemists how they *know* that bodies have an affinity for one another, the reply is, *because they combine together*. These answers show that such chemists have no very clear idea of what they talk about. They confound the notion of the act of combining with that of the power which causes the act of combination to take place. Whether any two given bodies can or cannot enter into combination is a point capable of being decided, either in the affirmative or the negative, by experiment, and by *that alone*. But no experiment, or at any rate, no experiment which has yet been contrived, can show what is the nature of the governing influence which induces or obliges any two different bodies to combine together and produce a uniform compound possessed of marked and original properties. What we are told about *affinity* is mere gossip, and though the greatest chemists have given themselves up to gossiping, it does not follow that gossip is to be held sacred or venerable on that account. Wherefore, I caution all young chemists against giving implicit credit to what is said to them about *affinity*, and not to believe any assertion which is incapable of clear conception, or which is repugnant to common sense; nor yet to value that as knowledge and matter of fact, which, upon being closely examined, proves to be a mere play upon words. There has been more nonsense written about this affinity, and more ugly diagrams drawn in illustration thereof, than about any other subject connected with chemistry. And the reason that so much nonsense has been written and published, is, simply, that chemists have been desirous of enveloping their ignorance in a cloak of mystery. There stood the plain fact before the world,—*that bodies combined together, and Chemists knew not why*, and the chemists not liking to *say* so, and not liking even to *think* so, persuaded themselves, and then tried to convince the world, that they DID *know why*. They said that bodies combined together *in virtue of their affinity for one another*. This was pretty. The credulous vulgar stared, and amazement gave place to belief.

You prove, by an experiment, that two given bodies are actually capable of entering into combination; you prove, in the same way, that, under particular circumstances, two other bodies are incapable of combining together. You inquire what it is which in the one case *causes* the combination to take place, or in the other case *prevents* the combination from taking place. You are told that the first two bodies combine because they have an affinity for one another, and the latter two do not combine because they have no affinity for one another. Now, as you are told, on the other hand, that the existence of an affinity between two bodies is proved by the act of combination, and by that act alone, it is plain that this relation may be expressed in other words, as follows:—the first two bodies combine, *because they combine*, and the last two do not combine, *because they do not combine*. Is there any *use* in this sort of explanation? Does it give you any idea of the nature of the power which influences combination? Is the doctrine of chemical affinity anything but twaddle?

I know that bodies *do combine*, but I do not know what it is that makes them combine, or why it is that, in some cases, combination is effected with difficulty, in others with facility. I cannot perceive that any point is gained by ascribing it to *affinity*, which is merely a word without an idea. I consider it sufficient for the communication of knowledge to say, that such and such substances, put together under particular circumstances, either *do* or *do not* combine; and I see no reason for adding the *sham explanation*, that it is BECAUSE they *have* or *have not* an affinity for each other.

Rejecting the doctrine of affinity, *in toto*, it is unnecessary for me to give any account of the multifarious *sorts* of affinity into which the ingenuity of sophists has divided the primary doctrine, or to explain the wonder-working nomenclature applied to it, specially to mislead, perplex, and mystify the ignorant and the unwary:—"Simple affinity—compound affinity—elective affinity—simple elective affinity—double elective affinity—complex affinity—disposing affinity—quiescent affinity—divellent affinity—reciprocal affinity—resulting affinity—*id genus omne*—

"May rosy dreams and slumbers light
Attend you all—good night! good night!"

I have included, in this edition of Chemical Recreations, a chapter on the FALLACIES which I consider as abounding in the prevailing doctrines of chemical science; fallacies, which set mathematics and logic at defiance, and convert a beautiful and simple theory into a bundle of paradoxes and absurdities. I have entitled this chapter the "Romance of Chemistry," and given the reader fair warning that what he finds therein is matter of pure speculation and opinion, resting upon the authorities adduced, and not based upon experimental evidence like the FACTS with which I have endeavoured to store the pages of other parts of the work. In reading the "Romance of Chemistry," therefore, I hope the student will bear in mind, that he is not called upon simply to *learn* and *believe*, but to *examine*, to *compare*, to *reason*, and to *judge*. I have endeavoured to explain the principles of philosophical reasoning, and wish my pupils to put them into practice, strictly and impartially. I contend for and recommend freedom of opinion, and the right of individual judgment in matters of science, and hope that no reader of this book will adopt as his own any doctrine advocated by me, without first ascertaining that it is founded in reason. It is a bad thing for a student to be too strong in faith.

The charge I bring against the prevailing theory of chemistry is a heavy one. I accuse its advocates of mystifying plain facts and propagating erroneous doctrines. I charge them with building a theory upon a basis infinitely too narrow for the science to rest upon, and with propping up their rickety theory with fallacies innumerable. I have stated these accusations in detail, and now await their refutation. Let those who have built up, or daily prop up, the system, defend it from my attack. If the dogmas denounced as *assumptions* can be vindicated as *demonstrations*, my accusations will come to nought. I trust it may be so. My crusade is against error, and I shall be delighted to learn that no error exists.

PORTABLE LABORATORY,

INTENDED AS

An Accompaniment to Chemical Recreations.

THE Publishers of Chemical Recreations will shortly have ready for sale, a small chest containing a collection of Chemical preparations and useful articles of apparatus, proper to furnish young chemists with the means of performing a series of instructive and amusing experiments. The greatest care will be taken to render this Laboratory useful, not merely to those who study at home, but to all who attend Chemical lectures, and particularly to medical students about to join the classes of practical chemistry. It will afford to those gentlemen the means of becoming acquainted with the properties of a great number of substances which pass frequently through the chemist's hands, and of familiarising them with the operations of which practical chemistry is constituted; while such as seek only for amusement will be supplied with materials for gratifying the most eager curiosity.

THE PORTABLE LABORATORY WILL BE PREPARED BY

Mr ROBERT BEST EDE,

CHEMIST TO HER MAJESTY.

The price of it will be One Guinea. Orders may be sent to any bookseller who supplies Chemical Recreations.

WORKS ON CHEMISTRY

PUBLISHED BY RICHARD GRIFFIN & Co., GLASGOW,

AND THOMAS TEGG & SON, LONDON.

A MANUAL OF ANALYTICAL CHEMISTRY, by Henry Rose, Professor of Chemistry at Berlin. Translated from the German, by John Joseph Griffin. In one volume 8vo. price 16s.

This is the most comprehensive work on Chemical Analysis which has yet been offered to the Public. It embraces not only the methods employed by the most accomplished chemists for determining the constituents of different compounds, but also the most effective processes for separating those constituents from each other. Great care is taken to point out the minutiæ upon the observance of which *success* and *accuracy* depend. It offers the most valuable assistance to all who occupy themselves with the details of experimental chemistry.

A PRACTICAL TREATISE on the USE OF THE BLOWPIPE in Chemical and Mineral Analysis. By John Joseph Griffin. In one small volume, price 4s.

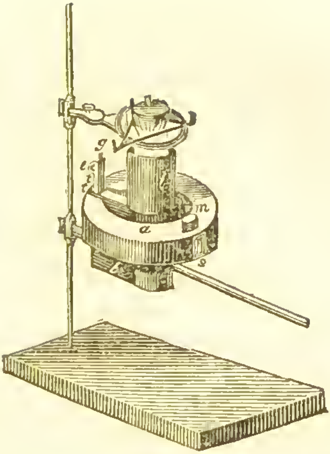
A DICTIONARY OF CHEMISTRY and MINERALOGY; with their Applications to the Phenomena of Nature, Medicine, Agriculture, and Manufactures. By Andrew Ure, M.D., F. R.S. The Fourth Edition, considerably enlarged, and illustrated by Engravings. One large volume, 8vo. double columns, price 21s.

THE DOMESTIC CHEMIST; comprising Instructions for the Detection of Adulteration in numerous articles employed in Domestic Economy, Medicine, and the Arts. To which are subjoined, the Art of detecting Poisons in Food and Organic Mixtures; and a Popular Introduction to the Principles of Chemical Analysis. In 18mo. with numerous cuts, price 4s.

THE ART OF GLASS-BLOWING, comprising Plain Instructions for making the Chemical and Philosophical Instruments which are formed of Glass. With numerous engravings, price 2s. 6d.

THE OPERATIVE CHEMIST, a Practical Display of the Arts and Manufactures which depend on Chemical Principles. By Samuel Frederick Gray. One large volume 8vo, 100 engravings, price 25s.

A HISTORY OF CHEMISTRY. By Thomas Thomson, M.D., F.R.S. In two volumes, small octavo, price 12s.



CHEMICAL MANIPULATION.

The following pages comprise an account of the operations resorted to in the performance of chemical experiments, and the apparatus essential to their successful execution. I state in every case the method of proceeding which is easiest and simplest, avoiding the description of expensive, or complicated instruments, and of difficult or troublesome processes; the student is thus spared the annoyance of acquiring useless knowledge, and his mind is directed solely towards what it is necessary for him *to get*, and what it is possible for him *to do*.

The notion, that a laboratory, fitted up with furnaces, and expensive and complicated instruments, is an absolute requisite for the proper performance of chemical experiments, is exceedingly erroneous. In fact, the truth is quite opposed to this opinion. "For general and ordinary chemical purposes," says Dr Henry, "and even for the prosecution of new and important inquiries, very simple means are sufficient: some of the most interesting facts of the science may be exhibited and ascertained with the aid merely of Florence flasks, of common phials, and of wine glasses. In converting these to the purposes of apparatus, a considerable saving of expense will accrue to the experimentalist; and he will avoid the encumbrance of various instruments, the value of which consists in show rather than real utility." It is a curious and instructive fact, that some of the most important discoveries in chemistry were made by persons who, either from choice, or motives of economy, used utensils of the very simplest character. The laboratory of the great Priestley cost a mere trifle; and it is well known how savingly Franklin went to work. The student will beware of procuring the large and showy apparatus which strike his eye from the lecturer's table, for they are useless to him.

I intend, in the present section, to give an account of the chemical processes of most frequent recurrence, and to describe with minuteness the instruments whose real utility, simplicity, and cheapness, entitle them to be so distinguished. I shall also inform the student where he may obtain the different utensils, and in some cases, how much they will cost him. And I shall notice the precautions necessary to be observed, in conducting processes, or in handling substances, that are dangerous or disagreeable to the operator.

Method, order, and cleanliness are essentially necessary in a chemical laboratory. Every vessel and utensil ought to be well cleansed as often as it is used, and put again into its place; labels ought to be put upon all glasses and boxes containing preparations. Apparatus and preparations should be kept on shelves, or in drawers, where they can be readily found when wanted. The care of cleansing and arranging vessels, which seems to be trifling, is very fatiguing and tedious; but it is also very important, though frequently little observed. When a person is keenly engaged, experiments succeed each other quickly; some seem nearly to decide the matter, and others suggest new ideas; the experimentalist cannot but proceed to them immediately, and he is led to pass from one to another; he thinks he shall easily know again the products of the first experiments, and therefore does not take time to put them in order; he prosecutes with eagerness the experiments which he has last thought of; and, in the meantime, the vessels employed, the glasses, and bottles, and products, so accumulate, that he can no longer distinguish them; or at least he is uncertain concerning some particular product. This evil is increased, if a new series of operations succeed, and occupy the laboratory, or if he be obliged to quit it;

for in these cases, every thing goes into confusion. Thence it frequently happens, that the chemist loses the fruits of much labour, and is obliged to throw away almost all the products of his experiments.

When new researches and inquiries are made, the mixtures, results, and products of all the operations ought to be kept a long time, distinctly labelled and registered; for these things, when kept some time, frequently present phenomena that were not at all suspected. Many fine discoveries in chemistry have been made in this manner; and many have certainly been lost, by throwing away too hastily, or neglecting the products.

The great agents whose aid the chemical analyst most frequently needs, are fire and water. When a process requires the first chiefly, it is said to be executed in the dry way; but when the latter is imployed, the operation is performed in the humid way. But, besides modes of proceeding which are purely chemical, and independent of the employment of chemical agents, the operator is frequently obliged to resort to processes entirely mechanical. The operations of chemistry might be naturally divided, therefore, into different classes, according to the several objects they have in view, and to the ways and means employed to accomplish those objects. All the operations which tend to change the form, without changing the nature, of a substance; those, for example, performed by the hammer, the knife, the pestle, and instruments of a like nature; and all those which determine the quantities of bodies are mechanical operations. But the operations performed by the aid of chemical powers and agents, and which separate the constituents of bodies, are purely chemical operations.

WEIGHING.

The beginning and end of every exact chemical process consists in weighing; and the best means of ascertaining the weight of bodies is by means of scales, which are therefore indispensable. What are termed apothecaries' scales, are very convenient for students who operate on small quantities and who do not aspire to the utmost degree of accuracy in their first attempts. These may be bought at Apothecaries' Hall (and perhaps at druggists' shops). They are put up in a little box, which, besides the scales, contains a series of weights, from half a grain to two drachms, in all about 20. These scales are sufficiently accurate for common purposes. The charge made for the box complete, is 4*s.* 6*d.* You must be careful not to use scales, or any other delicate metallic apparatus, in any place where acid vapours are flying about; for if you do, they will be seriously injured.

I have found these Apothecaries' scales to possess a high degree of sensibility. A pair which had been employed in ordinary operations for several years, and always without the protection of a glass case, gave upon being examined the following results: *a*, turned, when not loaded, with $\frac{1}{20}$ of a grain; *b*, turned, when loaded with 240 grains in each scale, with $\frac{1}{10}$ of a grain.

If a student, who has had some experience in chemistry, wishes to have a more sensible balance, he will be obliged to pay from 30 to 40*s.* for a good one. It is advisable to provide a glass case to protect such a balance from damp, or acid fumes.

Besides good scales, accurate weights are indispensable. These are best made of brass, or if small, of thin flattened platinum wire. They should be all grain weights, proceeding from $\frac{1}{10}$ of a grain up to 500 grains. A good variety of the small weights are requisite. Thin brass leaf or tin foil, cut into small slips, and clean lead shot, are very useful for counterpoises. A pair of very small brass pincers or forceps should be provided to lift up the weights, which ought never to be touched by the fingers, for handling is liable to soil them, and affect their weight.

Every time you are going to weigh, you ought to begin by examining whether your balance is accurate; and if not, you should justify it by putting a bit of wire or paper into the light scale, of sufficient size to make it counterpoise the other scale. The substance to be weighed is placed in one of the scales, and weights are placed in the other till the substance is counterpoised. Or the substance is first counterpoised, then removed from the scale, and weights are put in its place till the balance is again in equilibrium: this method is very good when the accuracy of the balance is doubtful.

When powders are to be weighed, they ought not to be laid on the scale of the balance, but upon a counterpoised watch glass, or what is better, upon very smooth glazed paper, the edges of which ought to be cut with scissars. The powders may be transferred by spatulas formed of platinum, of iron, or of paper. When crucibles are to be weighed after ignition, they ought not to be placed in the scale till sufficiently cool to be handled by the fingers. Volatile liquids must be weighed in closed vessels.

IMPERIAL STANDARD TROY WEIGHT.

grains.		*pennyweights.*		*ounces.*		*pound.*
24	=	1	=	$\frac{1}{20}$	=	$\frac{1}{240}$
480	=	20	=	1	=	$\frac{1}{12}$
5760	=	240	=	12	=	1

APOTHECARIES' WEIGHT.

pound.		*ounces.*		*drachms.*		*scruples.*		*grains.*
1	=	12	=	96	=	288	=	5760
		1	=	8	=	24	=	480
				1	=	3	=	60
						1	=	20

FRENCH DECIMAL WEIGHT.

Milligramme	=	0·0154 troy grains.
Centigramme	=	0·1540 ......
Decigramme	=	1·5406 ......
Gramme	=	15·4063 ......

MEASURING.—In a great number of experiments, it is necessary to be supplied with a determinate quantity of a liquid; as, for example, an ounce of water. This quantity may be estimated by means of the balance, but a great deal of time is saved by having an instrument by which the ounce of water can be measured. The subjoined figure represents *a graduated jar for measuring liquids.*

This is a cylindrical glass vessel, which holds, when filled to a certain mark made near the top, two ounces of distilled water, at the temperature of 60°; that is to say, it holds two ounces of clear cold water. It has other marks all down it, as low as one drachm; so that any quantity of water from one drachm (or, indeed, the half or third of a drachm) to sixteen drachms, may be readily obtained for any required purpose. Two troy ounces of water are equal to one-eighth of a pint, to 960 troy grains, and to $3\frac{6}{10}$ cubic inches..

But, besides the utility of this utensil for measuring water, it may be also employed, when the purpose does not require great accuracy, to measure liquids whose specific gravities are different from that of water. If, for example, you wish to obtain an ounce of sulphuric acid, you proceed as follows:—Knowing that the specific gravity of sulphuric acid is to the specific gravity of water, a little less than as 2 is to 1; and that, consequently, if an ounce of water occupies a certain number of divisions in this tube, then an ounce of the acid can only occupy a little more than half that number; you readily obtain an ounce of sulphuric acid by pouring that liquid into the tube till it rises a little above the mark for $\frac{1}{2}$ an oz. of water. You proceed in like manner for other fluids, calculating the bulk according to the specific gravity. It is by no means intended, by the recommendation of this manner of measuring liquids in general, to do away with more accurate modes; I only point out a method of proceeding calculated to save time in common cases.

Reduction of Solids to Powder.—*Pulverisation*, *Levigation*, *Trituration*. These, strictly speaking, are merely mechanical operations, by which bodies are reduced to fine powder, and rendered more fitting to undergo chemical action than they were in their compact form. This kind of process never separates from each other the elementary principles of bodies; for every particle of an impalpable powder, is a small whole, perfectly similar in its composition to the original mass from which it was divided. But, on the contrary, chemical action separates the constituents of a body.—Brittle substances are reduced to powder by means of *the pestle and mortar*. Some substances are reduced to powder by a dexterous use of the pestle round the sides of the mortar; in fact, by *rubbing*, and this is what is termed *trituration*. Reiterated blows of the pestle, which constitutes *pulverisation*, are made use of, to powder hard bodies in iron mortars. Only a small quantity of the substance to be powdered should be put into the mortar at one time. *Levigation* is generally performed by rubbing a body, sometimes with the addition of water, on a flat stone, with another stone, round on one side to suit the hand, and flat on the other, which is called a *muller*. A *spatula* or thin flexible knife, either of iron or bone, is employed to collect the substance under operation, from the sides to the centre of the flat stone or mortar. Bodies that are not brittle are reduced to small particles by means of *files*, *rasps*, *knives*, and *graters*.

MORTARS are made of a great many different substances; as, for example, of wood, glass, marble, porcelain, flint, agate, brass, and iron. In a large laboratory, where a great number of operations are performed, a great variety of mortars are necessary; but those which are most necessary to a student, are a mortar of porcelain or of Wedgewood's ware, and another of agate. In England, Wedgewood's ware takes place of porcelain, because it is more easily procured. Both substances have the property of resisting the action of acids. The Wedgewood's ware mortar ought to measure from 3 to 4 inches across the top. One of this size, which costs about 2*s*., is adapted to a great variety of purposes. The agate mortar may measure an inch and a half across the top. One of this size costs in Paris about 3*s*., but in London they are much dearer. If the student wishes to have an agate mortar to powder minerals for analysis, it ought to measure two and a half inches across the top. Such a mortar as this would cost 8*s*. in Paris, but nearly a guinea in London. The smaller agate mortar is sufficiently large for all blowpipe experiments, and for all cases of qualitative analysis. When an agate mortar cannot be procured, the student should procure a small porcelain or Wedgewood's ware mortar in its stead, as it is not convenient to powder very small quantities of a substance in a large mortar.

Iron and steel mortars are perfectly useless to a young chemist. When a solid mass of any substance is to be broken into smaller pieces, preparatory to trituration, it can be wrapped up in a piece of paper, and crushed by means of a hammer.

The agate mortar is employed in the trituration of very hard substances, such as minerals. Care is to be taken not to strike it strongly with the pestle; for, in consequence of the veins which intersect it, it is very liable to crack and fall to pieces.—The porcelain mortar is employed in the pulverisation of salts, and in the mixture of powders one with another.

The state of fineness to which a powder has been reduced, is judged of principally by the appearance. If the body be coloured, the colour becomes paler as the powder is finer, and generally at last almost wholly disappears. When the powder, from being dry and granular, assumes the appearance of moistness, and upon being touched by the spatula, preserves the form given to it by pressure, it is in a state of extreme division. In many cases, the progress of the operation can be judged of by rubbing a little of the powder between the finger and thumb, which is capable of detecting a very slight degree of grittiness. But this trial cannot be made without the loss of a little of the powder. The powder is transferred from the mortar by means of spatulas of platinum, silver, bone, or smooth paper. A card sometimes makes an excellent spatula, especially if glazed.

SIFTING and WASHING are performed to separate the finer particles of bodies from the coarser, which may want further pulverisation. For the operation of *sifting*, the well-known instrument called a *sieve*, is employed. *Washing* is used for procuring powders of a more uniform degree of fineness, than can be done by means of the sieve; but it can only be used for such substances as are not acted upon by the fluid which is used. The powdered substance is mixed with water, or other convenient fluid; the liquid is allowed to settle for a few moments, and is then decanted off; the coarser powder remains at the bottom of the vessel, and the finer passes over with the liquid. By repeated decantations in this manner, various sediments are obtained, of different degrees of fineness; the last, or that which remains longest suspended in the liquor, being the finest. Any cylindrical glass may be used for this purpose.

GRANULATION signifies the division of metallic substances into grains or small particles, to fit them for different purposes. It is performed either by pouring the melted metal into water from a considerable height, or by shaking it in a box, previously well rubbed with chalk, till the moment of congelation, at which instant it becomes converted into powder.

SOLUTION is effected when a solid put into a fluid entirely disappears in it, leaving the liquor clear. The body which thus disappears, is said to be *soluble*, and the liquid it dissolves in, is called the *solvent*, or *menstruum*. Sugar and salt are soluble bodies; for when they are put into water, they disappear entirely; but chalk is an insoluble body; for when that is put into water, it only makes the fluid *turbid*, or muddy, for a short time (being merely *diffused* through it), and then sinks to the bottom. Some bodies are capable of being dissolved in one kind of liquid, but not in another kind. Camphor, for instance, is soluble in alcohol, but insoluble in water. Metals are soluble, but their *solution* only takes place when they are put into acids. The operation of *solution* is more speedy in proportion as the substance to be dissolved presents a greater surface: on this principle is founded the practice of pounding, cutting, and otherwise dividing the bodies intended to be dissolved. The solution of a body invariably produces cold; and advantage has been taken of this phenomenon, to procure artificial cold, much greater than the most rigorous temperature ever observed in any climate. Solution is much accelerated by heat and agitation. But whether a cold liquid, or heat, or agitation should be employed in any particular case of solution, must be determined by the nature of the substance operated upon. In making solutions, it is necessary to use a vessel of such materials as shall not be acted upon by its contents, and of sufficient capacity to admit of any sudden expansion, or frothing, to which chemical action may give rise.

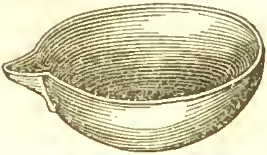
Solution is generally performed for the purpose of placing the substance operated upon in a state fit for chemical action. It is of two kinds. The first is that in which the liquid does not act chemically upon the substance which is dissolved. The second is that in which chemical action takes place. Solutions of the first sort reproduce the original substance upon being evaporated, but solutions of the second sort give a substance altogether different.

The fluid most generally employed as a solvent, partly because it furnishes solutions of the first sort, principally because it has a greater solvent power than any other liquid, is water. In certain cases, however, alcohol, ether, oils, acids, and alcalies, are employed as solvents.

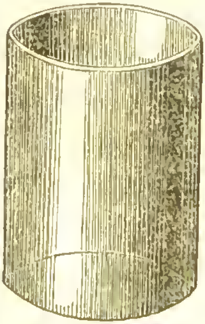
A SATURATED *solution* is one in which the liquid contains as great a quantity of the solid matter as it is capable of dissolving at the given temperature. A *dilute* solution is a mixture of a saturated solution with pure water.

The student should be provided with a variety of vessels for performing the operation of solution, a few of which shall now be described.

The Florence Flask, which is represented by the cut in the margin, is an instrument of great utility in performing the operations of digestion, solution, &c. Being made of very thin glass, it bears the sudden application of heat excellently; but, on account of *that thinness*, is very liable to be broken by a slight blow: it therefore requires to be handled carefully. The student should be provided with several of them. They are to be had of oilmen, who sell the empty flasks, after having disposed of the Florence oil they contained. Such flasks are extremely cheap. I have purchased them in London at a shilling a dozen. They contain nearly a pint.

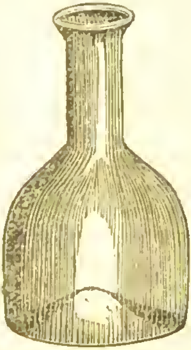


Wedgewood's Ware Basins, from 1½ to 5 inches in diameter, furnished with a lip, are very useful vessels. The substance of which these vessels are formed is so compact, that they are capable of supporting the sudden application of a strong heat, without breaking. They have also the advantageous property of being unacted upon by acids. The cost of these vessels is from *3d.* to *2s.* each.



A vessel of great utility, not only in solution, but in many other chemical operations, is a simple glass cylinder, free from any kind of ornament. Common tumblers frequently answer the purpose, but what are known in the glass-houses by the name of Confectioners' Glasses are preferable. Tumblers are generally too thick at the bottom, and on this account are liable to break when suddenly heated. The annexed cut exhibits the form of the Confectioners' Glasses. The student should be provided with glasses of this shape, capable of holding from a quart down to half an ounce. Those which contain two ounces are very useful vessels, as also are those which are capable of holding half a pint.

Wine glasses and ale glasses can be employed for the same purpose as these cylindrical glasses, as may also the glasses which are figured at pages 23, 24, and 30; but every species of fluting, ornamenting, or shank, is objectionable. When the substance to be dissolved is expected to require the aid of heat, vessels such as the following must be employed.



The figure in the margin represents a sort of phial, which is much employed by French and German chemists. It is made of thin green glass, which withstands equally well the action of heat or of acids. The bottom is turned a little inwards, so that it can stand alone without support, and is made thin, so that it can be exposed to a naked fire. The flint glass bottles sold in this country are much inferior to these continental glasses. Vessels the size of the figure are very useful for effecting the solution of small portions of a substance. Flint glass bottles of this size may be procured at the English toy-shops very cheap.

Extremely useful vessels for solution, especially when the operation is to be effected with the aid of heat, can be made of glass tube. The subjoined diagrams exhibit the forms which may be given to such vessels. Figure *a* represents a tube about the size of a quill, the glass of which is about the thickness of an address-card. The tube is closed at one end, and widened out a little at the other, which is open.

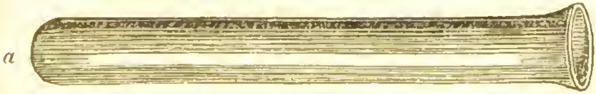
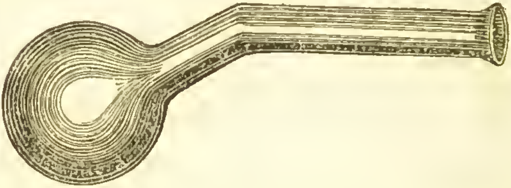


Figure *b* represents a tube of the same description, with a

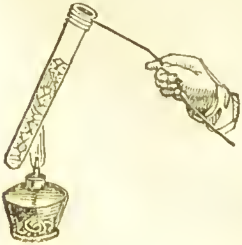
bulb blown at the end of it, so as to constitute a small matrass. Figure *c* represents a tube of the same description, with a bulb at one end, and a bend near the bulb; the object of which arrangement is to produce a small retort.

c

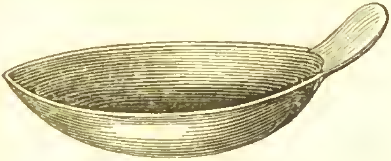


The student will find it useful to be provided with a great number of tubes similiar to figure *a*, in form, but different in size. They should be from one-fourth of an inch to two-thirds of an inch in diameter, and from 1 inch to 5 inches in length. A very useful size is three-eighths of an inch wide, and 4 inches long. Such tubes not only serve for effecting solution, but may be used as *test tubes*, and can be applied to many other purposes. He who is accustomed to the use of the blowpipe, should employ his spare time in working pieces of glass tube into these very useful forms; and the student who is unable to employ the blowpipe, ought to set about learning to do so without delay. Much loss of time, outlay of money, and practical inconvenience is avoided by him who is capable of preparing and employing these little vessels of glass tube. (See The ART OF GLASS BLOWING, or Instructions for Making Cheap Chemical and Philosophical Instruments, 18mo., London, 1831.)

When the liquid contained in a glass tube is to be boiled over a lamp, you hold the tube near the top with the thumb and middle finger of the right hand, and close the mouth of it with the fore finger; or you may twist a wire round the tube, and hold the end of the wire in your hand. It is prudent to adopt this plan when an explosion is to be apprehended.



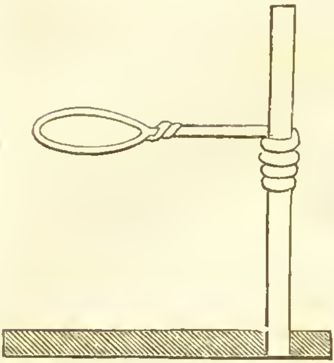
Watch glasses can often be advantageously employed when the solution of small portions of matter is to be effected. But an instrument, which, to a great extent, supersedes all small capsules of glass or porcelain, is that which is represented in the subjoined figure. It is a capsule of platinum, furnished with a small flat handle or ear of the same metal. The figure represents the full size of the instrument. The cost of such a vessel, when purchased of Mr Cary, in the Strand, London, or any other dealer in chemical apparatus, is about eight shillings. This outlay may be made by the student with ultimate profit; for the number of glasses saved from destruction by the common employment of a platinum capsule is very great. Glasses frequently break, or suffer corrosion, when heated over a lamp, either with dry matter or concentrated solutions. In every such case, the student loses a vessel and spoils an experiment. These accidents are obviated by the employment of a platinum capsule, which, moreover, can be advantageously made use of as a crucible cover in many important operations.



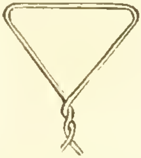
No substance must be heated in platinum vessels which can disengage either chlorine or reguline metals, otherwise the platinum vessel is liable to injury. For example, you must never heat mixtures of oxide of lead or copper with charcoal, or of peroxide of lead or manganese with muriatic acid, in these vessels.

A vessel similar to *c* (page 12) in form, but with a straight neck, and of large dimensions, is termed a MATRASS, or *bolthead.* Vessels of this sort can be bought at the glass houses. They are purchased by weight. Such as are from two or three inches diameter in the bulb, and about 6 inches long in the neck, are useful in effecting the solution of metals and in various other operations. The bottom or round part of the bulb of such vessels ought to be thin, otherwise they crack when heated suddenly.

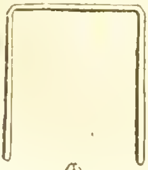
When you wish to support a capsule, a flask, or a retort, over a lamp, you must employ a piece of apparatus, generally called a Retort stand. This consists of a brass or iron

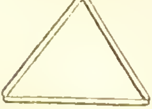


rod one third of an inch thick, and sixteen inches long, driven into the end of a piece of board, five inches wide, and nine inches long. It must be furnished with a horizontal arm, having a ring or a triangle at one end, and a coil or worm at the other. This arm must be made of iron wire about one-eighth of an inch thick. You form the worm by fixing the large rod and the end of the wire in a vice, and then coiling the wire four or five times round the large rod. Such an arm moves loosely up and down the rod, but becomes fixed when a weight is placed on the ring. This ring can be made to support any sort of apparatus however small. You have only to lay upon it various-sized triangles or trellis work of fine iron wire. When you want to heat a crucible, the thinner the wire by which it is supported, the more powerfully the heat is enabled to act upon it.



A simpler species of retort stand, but also a less substantial species, is constructed as follows:—You take three pieces of iron wire, one eighth of an inch thick, and about sixteen inches long, and bend each piece into the form of the adjoining upper figure. You then bind them together, by two and two, at the angles, with thin wire; by this means you produce a frame, the upper surface of which is a triangle, like the lower adjoining figure. The glass vessel to be heated is placed upon this triangle, and the spirit-lamp is placed below it, between the legs of the stand. This kind of support can be readily prepared and is both economical and portable.





Stirrers are necessary to be provided. They should be prepared of glass rod, or stout tube, about one-fourth or one-third of an inch in diameter, and from 4 to 10 inches long; and ought to be closed and rounded at the ends.

LIXIVIATION is used for separating such substances as are soluble in water from such as are insoluble. Suppose, for example, it is required to separate the *sand* from a mixture of sand and salt: the compound body is placed in water; the salt is dissolved by the water; the sand is diffused through it. The mixture is filtered; the salt passes through with the water; the sand remains on the filter. The apparatus used in filtration, with the addition of a jug, is all that is required for this operation.

INFUSION is performed when a hot liquor is poured upon a substance that is partly soluble and partly insoluble, in order to extract something from it. The making of *tea* is an instance of the performance of this operation.

DIGESTION.—This operation consists in soaking, for a long time, a solid substance in a liquid kept constantly hot.

MACERATION.—The continued steeping of a solid body in a cold liquid. Ink is produced by macerating the materials of which it is composed.

When a solution has been obtained, the solid matter may be regained from it, in some cases by evaporation, in others by precipitation. Evaporation generally produces the substance previously contained in the solution, but precipitation affords something different.

EVAPORATION.—When a liquid is exposed to heat, it is converted into vapour or gas, which, if the vessel containing the liquid be open, flies away. The liquid thus heated, is said to evaporate, and the operation of heating the liquid is called evaporation. If the liquid which is evaporated, held in solution, a substance of a fixed nature, this substance, after the evaporation of the liquid, remains behind in a solid state. The operation of evaporation is often employed by chemists on this very account. If the student possesses a mixture of salt and sand and wishes to obtain the salt in a separate state, he lixiviates the mass, filters the liquid containing the salt, from the insoluble sand, and afterwards exposes it to evaporation. He thus obtains a product of clean dry salt, totally freed from sand.

The vessels in which evaporation is performed ought not only to be able to resist heat, but also the corrosive action of acids and alcalies, which often act in a very powerful manner, when present in concentrated solutions. They ought, moreover, to be of such a form as to expose a large surface of liquor to the atmosphere. Capsules of porcelain or Wedgewood's ware (page 10), or of silver or platinum (page 13) are most generally employed. Watch glasses, broken pieces of Florence flasks, and crucibles of porcelain and platinum, can be used for the same purpose, and even flat plates of glass are useful when single drops of a solution are to be evaporated. The vessels used for evaporation should always be thin at the bottom, in order that they may bear, without breaking, the sudden application of heat.

The vessel in which a solution is evaporated, should, during the operation, be covered; partly to prevent the contamination of the product by dust, and partly to prevent a loss of matter by ebullition or spirting. When the evaporation is slow, two glass rods may be laid across the capsule and a double fold of blotting paper be laid upou them. This paper should be changed as often as it becomes so soft, or so much corroded by acid steams, as to be liable to fall into the solution. A different method of protecting the capsule, consists in putting another capsule upon it, and filling the upper capsule with hot sand, to keep it from condensing the steam which rises from the solution. Small capsules, or a crucible, may be covered by the platinum capsule (page 13), placed upon them in such a manner as to allow a space for the escape of the vapour. In all cases, the cover must dip downwards, in order that the fluid, which is thrown upwards, or condensed upon it, may return to that below. If the convex side of the cover were uppermost, particles of matter existing in drops of the solution could be conveyed to the outside of the vessel and cause a loss.

The contents of a capsule should be frequently stirred during evaporation, by means of a glass rod. Lumps of saline matter, and hard dry crusts should be broken down with great care.

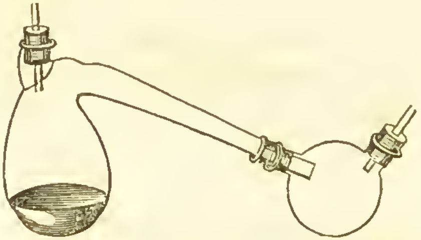
When a solution is to be evaporated to dryness, much caution is necessary in conducting the operation at the period when the mixture becomes thick. A very gentle heat must then be applied, and tho mixture of solution and solid matter must be stirred continually. If this care is not taken, part of the contents of the vessel are invariably thrown out by the sputtering of the pasty mass. All hard lumps which appear must be broken down, and the powder be well mixed with the moist substance. If the lumps are too hard to be broken by a glass rod, a small pestle may be employed for that purpose; care being taken, in the case of an analysis, to wash from the pestle the matter which may adhere to it, and to preserve the solution to be added to that formed by the subsequent solution of the evaporated mass.

When large quantities of liquid are to be evaporated at a boiling temperature, as, for example, when a mineral water is to be concentrated for analysis, the evaporation may be effected in a Florence flask.

Distillation.—As, during evaporation, the fluid carried off in the state of vapour, is entirely lost, being sacrificed for the sake of the fixed substances with which it was combined, and which remain behind, this process is only employed when the fluid is of small value, as water, for instance. But, when the fluid is of sufficient consequence to be preserved, we have recourse to a process termed *distillation*.

Distillation is evaporation performed in close vessels, composed of different materials, and varying in their forms. The vessel usually employed, in the large way, is called a *still*. It consists of a copper vessel, of the shape of a tea-kettle, but without its spout and handle, enclosed in the brick-work of a furnace. Into the opening of this vessel, instead of a common lid, a movable head is affixed, which ends in a narrow open pipe. This pipe is received into what is called a *worm*, which is a tube of lead, twisted spirally, and fixed in a wooden tub, so that it may be surrounded by cold water. When the apparatus is to be used, the liquid intended to be distilled is put into the body of the still, and the head is fixed in its place, the pipe, which terminates it, being received into the leaden worm. A fire is then kindled in the furnace, and the liquid is raised into vapour, which passes into the worm, is there condensed by the surrounding cold water, and flows out of the extremity of the pipe into the vessel placed to receive it.

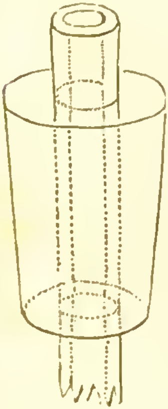
The common still, however, can only be employed for volatilizing substances that do not act on the copper or other metal of which it is made; and it is, therefore, limited to a few operations. The vessel which is most employed by the chemist in the operation of distillation, is the *retort.* It is a pear-shaped vessel of glass, similar in form to the figure given below. In the top of the body, or wide part, is an opening, or tubulure, through which the materials to be distilled are inserted. This opening can be closed by a cork or by a glass stopple, ground so as to be air-tight. Retorts are sometimes made without the opening at the top, they are then cheaper, and are called *plain* retorts; but those with the opening, called *tubulated* retorts, are, in many cases, more convenient. Retorts are also made of earthen-ware, and of metal.



A necessary appendage to the retort, is a *receiver*. This is a vessel of glass, generally of a globular form, though not always so. The annexed figure represents a tubulated retort, connected with a tubulated receiver. The tubulure of each of these vessels is stopped with a cork provided with a glass tube. Sometimes the neck of the retort is much too small to fit closely the neck of the receiver. In that case, a cork must be provided that fits the latter, and must have a hole burned or bored through it, of a sufficient size to hold the former. The plan with a cork will not answer, however, when corrosive fluids are distilled. You must then use an instrument of glass, called an *Adopter.* This consists of a glass tube, shaped like a rolling-pin, one end of which takes in the mouth of the retort, and the other end of which goes into the mouth of the receiver. The joinings are secured by corks or lutes, according to circumstances.

Glass retorts may be heated by means of lamps, properly regulated, to make a regular flame. Earthenware and iron retorts are exposed to the naked fire.—In order that the vapour may be condensed as fast as it comes over from the retort, the body of the receiver is either placed in a tub of cold water, or kept cool by the continually-renewed application of wet cloths or wet blotting-paper. It can also be kept cool by means of a small stream of cold water, so contrived as to run continually from the point of a little glass syphon, placed in a pan of water.

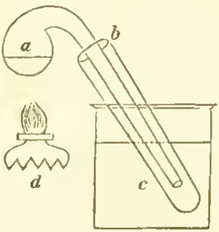
It is necessary to be provided with retorts of various sizes, from two ounces to a pint. In selecting at the glass-house a retort, or any other utensil intended to be placed over a lamp or in a sand-bath, be careful to take one with as thin a bottom as can be got. Thin glasses are the only ones that will bear the sudden application of heat; thick ones break immediately upon being put to the fire. The little tube vessels described at page 11, serve both as retorts and receivers, in a great number of cases; and the student who can use the blowpipe, is able to modify their forms with the greatest facility.



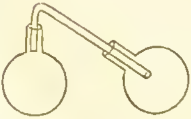
In many cases, a flask can be employed, instead of the retort, as a distillatory vessel. It is necessary, in that case, to connect the flask with the receiver, by means of a glass tube, bent so as to form an obtuse angle. The figure in the margin exhibits a piece of tube of the size and strength commonly employed in operations of this nature, and which is passed through a perforated cork, of the size necessary to fit the mouth of an ordinary flask. This species of tube is very much employed in the conveyance of *gases*, from the vessels in which they are generated into those prepared for their reception.

The substances which are to be subjected to distillation should be put into the retort with care. When it has a tubulure, they are to be inserted thereby. Solid bodies ought not to be dropped in so as to fall suddenly upon the bottom of the retort, otherwise they will make a hole and fall through. The retort should be inclined, and the pieces, reduced to a small size, allowed to slide in gently. If there is no tubulure, care should be taken, in placing the charge into the retort, not to soil the neck, otherwise the vapour which rises during the distillation will wash the neck of the retort, and convey the impurities into the receiver. If the neck of the retort is first made very clean and dry, solid substances may be passed in without soiling it; and liquids ought to be inserted by a funnel, having a glass tube neck, sufficiently long to reach into the body of the retort and project beyond its mouth. When a liquid has been poured through such a funnel into a retort, the funnel should be carefully withdrawn, and in such a manner that the drop of liquid resting at the point of the funnel does not touch the interior of the neck of the retort. This is best managed by holding the retort so that the opening of its neck is rather lower than the part which joins the body of the retort.

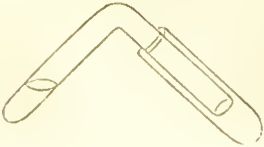
The charge put into a retort ought seldom to occupy above one-third of its capacity. When a greater proportion of materials is inserted, the mass is liable to boil over.



When a very small retort is required, and the distilled product is easy of condensation, an apparatus of the description hereby depicted may be made use of. *a* is the retort, *b* a receiver formed of glass tube, *c* a vessel of cold water, acting the part of a worm-tub. It is easy to connect *a* to *b* loosely, by a cork or a fold of paper. *d* is the flame of a spirit-lamp.



The annexed figure exhibits another form of distillatory apparatus, which may be employed when small quantities of substances are operated upon. It consists of two small bulbs, blown out of a glass tube by means of the blowpipe. One serves for a retort, and the other for a receiver, and the two are connected by a narrow glass tube.



The simplest of all retorts and receivers are those formed of small tubes without bulbs, which can be set together in the manner shown by the figure. They are extremely useful in small experiments.

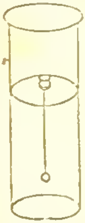
Sublimation.—This is a process, by which volatile substances are raised by heat, and again condensed in the solid form. This operation is founded on the same principles as distillation, and its rules are the same, as it is nothing but a dry distillation. The apparatus for sublimation is very simple. Many substances, upon being exposed to heat in a small glass tube (see page 11), sublime and condense upon the upper part of the tube. Berzelius recommends the insertion of a small crucible within a large one. The substance, upon being heated in the large crucible, condenses upon the under side of the small one. It is sometimes sufficient to cover a small capsule with a large one, or with a cone of paper; while in other cases, the vaporised body has to be conveyed into a flask by means of a conducting tube. An *alembic* is a flask with a wide mouth, and a capacious hollow stopple, or *head*, adapted to it. This vessel was formerly much employed in distillation and sublimation. The vaporised matter condenses in the head, whence, if liquid, it is permitted to run off by a spout.

Crystallisation.—When fluid substances are suffered to pass with adequate slowness to the solid state, the attractive forces frequently arrange the ultimate particles of the substance in such a manner as to form regular geometrical solids, to which has been given the name of *crystals*.

Perfect mobility among the corpuscles is essential to crystallisation. The chemist produces it either by igneous fusion, or by solution in a liquid. When the temperature is slowly lowered in the former case, or the liquid slowly extracted by evaporation in the latter, the attractive forces resume the ascendency, and arrange the particles in symmetrical forms. Bodies, in crystallising from their watery solution, frequently retain a small portion of water, which remains confined in the crystals in a state of solidity, and does not reappear till the crystalline form of those bodies is destroyed. This is called the *water of crystallisation*. The operation of crystallising is of great utility in the purification of various saline substances. The mode of obtaining crystals of certain bodies, differs according to the nature of those bodies. If it be desired to obtain crystals of a salt that is more soluble in hot water than in cold, (there are many salts of this kind,) all that there is to do, is to put into hot water as much of that salt as it will dissolve, in short, to make a hot saturated solution, and then to allow it to cool gradually; the slower the better. As the heat which contributed to the fluidity of the salt flies off, crystals will be deposited at the bottom of the vessel. Salts that are soluble in equal parts of hot and cold water, can only be crystallised by driving the water of solution off in vapour. But this must be done very slowly; for rapid evaporation leaves a salt, not in a crystallised state, but in that of a solid irregular mass. By the operation of crystallisation, salts which differ in their degree of solubility, or whose solution is unequally accelerated by heat, may be obtained separately from the same liquid. Thus, if two salts be dissolved in the same liquid, and one of them be much more soluble in hot than in cold water, and the other be equally soluble at any temperature, then, on evaporating the solution sufficiently, the latter salt will crystallise while the liquor is hot, whereas the other will not shoot into crystals until the liquor is cold; thus, by alternate evaporation and cooling, the two salts may be obtained uncombined, though perhaps with a little intermixture of each other.

The only general rule that can be given, for the purpose of directing you how to crystallise bodies, is this: slowly evaporate the solution, until a pellicle, or thin skin, is formed on the surface of it; then set it in a cool place, where it will be free from dust, and can remain undisturbed. This rule will not, by any means, apply to all salts, nor is there any other rule that will. Nothing but experience, and a knowledge of the habitudes of the various crystallisable substances, can be of much avail.

Many saline solutions, when set by to crystallise, throw out ramifications of dry salt, which creep over the edge of the basin, and, if not interrupted, extend over the entire outer surface of the basin, and along the contiguous table. This is prevented by rubbing a little tallow round the edge of the basin. When a hot solution is to be cooled slowly, the vessel should be placed on a cushion, and covered with a few folds of cloth. When a cold solution is to be exposed to spontaneous evaporation, a process which produces large and regular crystals, the vessel should be placed in a dry situation, and be left uncovered, or only be covered with a piece of paper to keep out the dust. When crystallisations are performed on the small scale, flat plates of glass, watch glasses, and the platinum capsule (page 13), are useful; but in general, deeper vessels are preferable. A solution set by to crystallise, should be contained in a vessel so shaped that the liquid may be about twice as wide as it is deep. Consequently, very shallow or very narrow vessels are not so well adapted for this operation as those are which have the form of basins. Rough surfaces and porous substances promote crystallisation.



The following is a neat way of promoting the crystallising of salts in small solutions. Put a cold saturated solution of any crystallisable salt into a deep jar, and hang in it a line of silk or horse-hair, fastening a shot to the bottom of the line, and a bit of cork to the top. Set the solution aside, and you will soon perceive crystals to form about the shot, and along the line. Sugar will crystallise on threads fixed across a pan.

NEUTRALISATION.—*Action of Acids on Vegetable Colours.* Mix a little tincture of cabbage with a glass of water so as to form a clear blue liquor. Drop into the mixture a little sulphuric acid. The colour will then turn red. Every other acid produces the same change.

Make a blue mixture of water and tincture of litmus, and add a few drops of any acid to it. The colour will turn to red.

Put a drop of any acid into a glass of water and dip into the mixture a slip of blue litmus paper. The colour of the paper will be changed to red.

Action of Alcalies on Vegetable Colours.—Into a mixture of water and tincture of cabbage, pour a few drops of liquid ammonia or of a solution of potash. The blue colour of the liquor will turn to green. All alcalies produce this change.

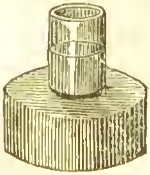
Make a yellow liquor by mixing tincture of turmeric with water. Add a little liquid ammonia or solution of potash to this liquor. The colour will become brown.

If you mix water with any alcali and then dip into it a slip of turmeric paper, its yellow colour will be changed to brown.

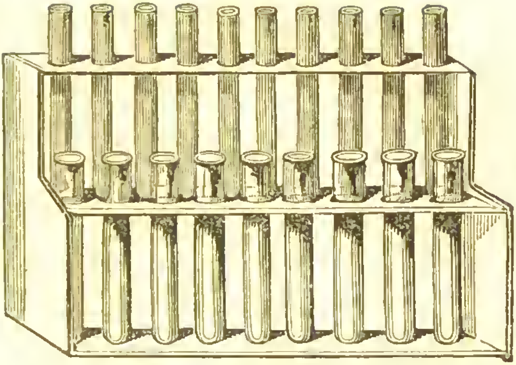
Counter Actions.—If you add an alcaline liquor to the tincture of cabbage which has been reddened by an acid, the liquor first regains its blue colour and finally becomes green. If you add an acid to the tincture of cabbage which has been rendered green by an alcali, the liquor becomes first blue and finally red.

The reddened litmus paper regains its blue colour in an alcaline solution, and the browned turmeric paper regains its yellow colour in an acid solution.

Remark.—When a liquid effects no change in the colour of turmeric and litmus, it is said to be *neutral.* When it turns blue paper red, it is said to be *acid.* When it turns yellow paper brown, it is said to be *alcaline.* When you render an acid liquid alcaline by adding an *excess* of an alcaline solution to it, you are said to *supersaturate* the liquid. If you then render the supersaturated solution neutral, by adding a certain quantity of acid, you perform what is called *neutralisation.* In trying the neutrality of a liquid, you may either dip the end of the test paper into the liquid, or touch the edge of the test paper with the point of a clean glass rod dipped into the liquid for trial. The latter method is the cleaner of the two.



TESTING.—The nature of tests has been already explained. I have to speak here of the methods of applying them. The liquid to be tested should be put into a small wine glass or into a tube of the annexed form, two thirds of an inch wide and three inches long, or a test tube such as figure *a* (page 11). The last mentioned is the vessel best adapted for this purpose, because it admits of being exposed to heat, which the others do not. The best size for test tubes is five inches long, and nearly half an inch wide. A single tube can be supported by a large perforated cork. But as in general a great number of tubes are employed in testing a solution, it is proper to be provided with a small frame which can hold nineteen of such tubes in two rows, the glasses in the upper row being rather smaller than those in the under row, and the largest being of the size above mentioned, namely, five inches long and half an inch wide. Such a frame is figured in the next page.

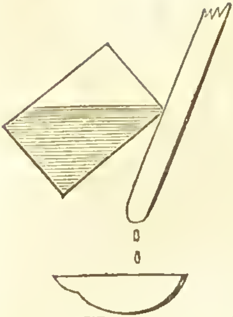


Another way of supporting test tubes is by means of a piece of trellis work formed of fine wire and provided with legs of wire or wood.

It is necessary to take a very small quantity of the liquid to be tested; if it is scarce, three are four drops will be sufficient; if it is plentiful, as much as fills half an inch of the tube, may be taken. The tests to be applied are generally in a liquid state, and they must be added in very small quantity. When a test is very sensible in its indications, you may dip the end of a clean glass rod into the liquid test and then stir the liquid in the test tube with the wetted end of the rod. When a tube is dipped into oil of vitriol and then into a clear solution containing barium, you immediately observe the formation of a white precipitate of sulphate of barytes. If the test to be applied is not very sensible in its indications, a more considerable quantity must be applied. Occasionally, it is necessary to add a considerable quantity of the test, in order to re-dissolve the substance precipitated by a small quantity of the test. It is always improper to add the test liquid in large quantity at first; the proper method is to drop it in gradually.

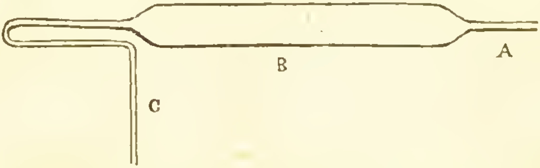
When extremely small portions of a liquid are to be tested, it is a good plan to employ flat plates of clear glass. The unknown liquid is applied to the glass in drops by means of a glass rod, and the test is added to it in the same manner.

Decantation.—If you wish to remove a liquid from a solid which has subsided in it, or if you want to pour a liquid from

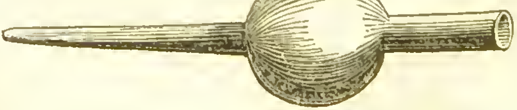


a wide mouthed vessel into a narrow mouthed vessel, you may proceed as follows:—Apply a little tallow to the edge of the large vessel, dip a glass rod into the liquid, hold the middle of the wetted glass rod against the tallow, and then by inclining the large vessel, make the liquid run gently down the rod into a vessel placed below the point of the rod to receive it. The tallow prevents the liquor from running down the outside of the large vessel. You must perform this operation without losing a single drop of the liquid.

If the sediment be so light as to mix readily with the liquid when the vessel is gently moved, it is necessary to draw off the liquid without moving the vessel. The following figure exhibits an instrument which is very useful in such a case. The part B may be three or four inches long and nearly an inch wide, the part A four inches long, and the descending part C, sufficiently long to reach to the bottom of the vessel from which the liquid is to be withdrawn. In applying the instrument, you dip C into the liquid, and then, by applying the mouth to A, you suck the liquid into the reservoir B.

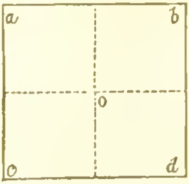


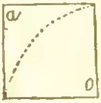
Another instrument which can be usefully employed in transvasing small portions of liquid, is the *dropping tube* figured hereby. This consists of a glass tube having a bulb in the middle, and one end drawn out to a fine point. The

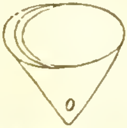


instrument should be twice as large as the figure. You put the narrow point into the liquid, and suck the liquid into the bulb: you then close the orifice of the tube with your tongue, remove the point of the tube into another vessel and then, by opening the upper end of the tube, permit the liquid to run out. Take particular care not to suck the liquor into your mouth.

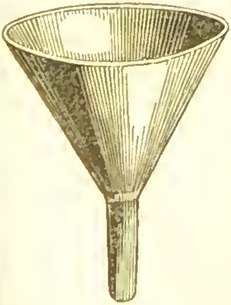
Filtration.—When a solution has been prepared for examination, it ought to be perfectly clear. If it appears muddy or troubled, it must be filtered through a proper filter, by which means it is separated from the solid matters which make it appear opaque. Take a piece of filtering paper about two inches square; fold it in half, so as to bring the corners *c d* upon the corners *a b*; then fold it again, so as to bring the four corners together at *a*; cut off the corners, so as to form a quadrant, in the manner shown in the under figure *a o*; and, finally, open the first fold, so as to produce an inverted hollow cone. The letter *o* points out the position of the centre of the paper in all the figures.

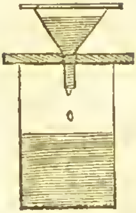


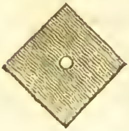




Procure a glass funnel, of the size and form of the annexed figure. This is large enough to hold most precipitates which occur in qualitative analytical experiments. Very often smaller funnels, made of tube, are useful, and sometimes large funnels are necessary. They must always be made of glass. The paper filter, folded in the manner described above, is exactly formed to fit a funnel of this shape. But the English funnels are generally narrower and longer than this figure, and such funnels are extremely objectionable. The filter, when placed within the funnel, must not come within an eighth of an inch of the top, otherwise the liquid which may be poured into it is liable



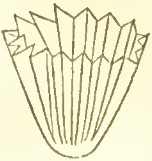




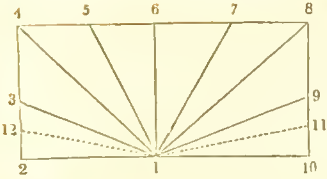
to run over. The neck of the funnel should be placed through a hole made in the middle of a square piece of thin board, or of stout pasteboard, and the board should be laid on the top of the glass cylinder intended to receive the filtered liquor. When the access of atmospheric air is to be avoided, the funnel must be covered with a plate of glass, and if the air is to be utterly excluded, the edge of the funnel and the surface of the glass plate must be ground. When the filtering apparatus is placed together, in the manner shown by the last wood-cut, the liquor to be filtered is to be decanted into the paper, with the help of a rod, as described in the article on "Decantation." The liquor should never be permitted to rise quite to the top of the paper filter, otherwise it will escape between the paper and the glass, and then run down into the clear liquor, and oblige you to perform the whole operation over again. The fuller you keep the filter, however, the quicker the filtration proceeds. Keep it therefore nearly full, but do not let it run over.

If you wish to filter broth, ar any mixture containing animal matters, first run it through muslin to clear it of the heaviest part of the solids it contains, and filter it through paper afterwards.

The paper generally employed for filters is white blotting paper. Berzelius recommends Watt's patent copying paper. Some persons employ India paper for nice purposes. The first portion of liquid which passes through a filter has generally to be refiltered, being often slightly turbid. But when the fibres of the paper are swelled by moisture, the liquor passes through in a more transparent state. It is a good plan to moisten the filter with a few drops of distilled water before you begin to pour in the solution. This enables you to fix the paper neatly in the funnel.



When you wish to filter a liquid rapidly, to free it from impurities, it is proper to employ a folded or ribbed filter, like the annexed figure. Take a square piece of paper, fold it into two, by doubling the corners *c d* upon the corners *a b*, as directed above; then make the folds shown

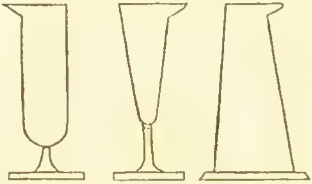


by the annexed diagram, and let them all bend on the same side of the paper. To produce 1 to 6, fold 10 upon 2; to produce 1 to 8, fold 10 upon 6; to produce 1 to 9, fold the line 1 to 10 upon the line 1 to 8; to produce 1 to 5, fold 2 upon 8; to produce 1 to 4, fold 2 upon 6; to produce 1 to 3, fold 2 upon 4; to produce 1 to 7, fold 10 upon 4. You have now 7 folds, all on one side of the paper, namely, folds 3 to 9. Next make a fold *between each of the above folds*, so as to rise on the other side of the paper. Begin by folding 1 to 10 upon 1 to 8, and turn back 1 to 10 upon 1 to 9. You will thus produce the reversed fold 1 to 11. Proceed in the same way to make a reversed fold between each of the other folds. When the paper is folded up, it looks like a child's fan. Cut off the projecting parts, so that the paper may look like a circle if opened out. Gently separate the two sides of the filter, and form it into a little cup. Put your finger into the cup, and push out the bottom till it is round. Upon examining the opened filter at the parts marked 10 and 2, you will find that there are two folds bending the same way. This defect you correct by making a small additional reversed fold in the parts which lie between 10 and 11, and 12 and 2. In rubbing down the folds, do not rub the paper near the centre 1, otherwise you will produce a hole. The funnel best adapted to contain a folded filter, is higher and narrower than the funnel figured above (page 27.)

PRECIPITATION.—When two limpid solutions are mingled together, and chemical action is excited, the whole mixture often becomes turbid, and a solid powder, in a state of extreme division, falls to the bottom of the vessel. This powder is called a *precipitate*, the agent employed expressly to produce it, is called a *precipitant*, and the operation which causes its production is called *precipitation*.

Precipitation is extensively employed in analytical chemistry. In qualitative analysis it is used to demonstrate the presence of certain bodies in solution; and in quantitative analysis, it is employed to separate the bodies contained in a solution from one another.

The best vessels for precipitation in qualitative analysis are *test tubes*, formed of white glass, five inches long, and about half an inch in diameter. You should be provided with a considerable number of these tubes, and a stand to hold them, such as has been described at page 25.



In quantitative analysis, where the precipitates are often of considerable bulk, the best vessels for precipitation are plain cylindrical glasses, such as the confectioners' glasses, described at page 10. You may also use vessels such as are figured in the margin. They should be of various sizes. It is useful to have a few with the edges ground smooth on a stone. These can be closed air-tight by the application of a piece of ground plate-glass. This is very necessary in certain operations, in which the exclusion of atmospheric air is indispensable to the success of the operation.

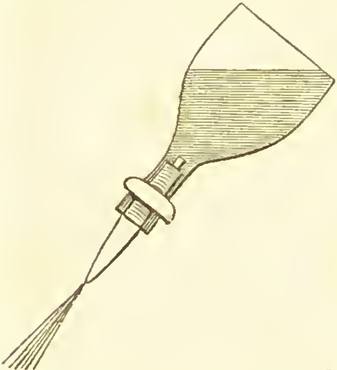
Precipitation is sometimes promoted by the presence of alcali or acid in excess. This depends upon the properties of the particular substances which are operated upon. It is in general promoted by agitation, and still more by heat. When the application of heat is absolutely necessary, the operation is sometimes best performed in a porcelain or platinum capsule, or in a Florence flask. Occasionally, the solution is first heated, and then mixed with the precipitant; in other cases the solution is warmed after the precipitant is added: this is done to make the precipitate fall down properly, and become fit for filtration. Rose, in his "*Manual of Analytical Chemistry*," describes particularly the cases in which the one or the other of the above methods is to be followed. The presence of vegetable matter in metallic solutions often hinders the formation of precipitates, which would otherwise be produced. For precise information on this point, I refer you to Rose's book, cited above.

If you have a substance in solution, and wish to precipitate it entirely, you may proceed as follows:—Add a small quantity of the precipitant, mix it well with the solution by stirring it with a glass rod, and then allow the whole to settle. As soon as the upper part of the solution has become clear, add a single drop of the precipitant. If this causes a troubling, add a little more of it. Stir the whole well together, allow it to settle again, and then test it afresh with another drop of the precipitant. Proceed thus until the addition of a single drop of the precipitant causes no opalescence in the supernatant liquid. Towards the end of the operation, the precipitant should be in a dilute state, provided it be of importance that no excess of it should be added to the solution. It is extremely difficult to hit the exact point of neutralisation—to add precisely enough of the precipitant, without adding too much. In general, precipitation is most completely effected when a slight excess of the precipitant is added to the solution; though sometimes the effect produced by adding an excess of the precipitant is the re-solution of the precipitate. When, however, the precipitant is cheap, does no harm to the precipitate, and is not injurious to the resulting solution, it is advisable, rather to effect the precipitation by adding an excess, than to lose time by delicately attempting to effect an exact neutralisation.

EDULCORATION.—After having precipitated a substance, it is generally necessary to effect a complete separation of the precipitate from the solution. You must allow the precipitate to subside. It sometimes falls down very slowly; sometimes very quickly: in general, the subsiding is facilitated by gently warming the solution. In the meantime, you prepare a filtering apparatus, like that depicted at page 28, and when the supernatant solution is clear, you decant it into the filter, taking the precaution of not disturbing the precipitate. When the clear liquor has nearly all passed through the filter, you stir up the residue with the precipitate, and bring the whole upon the filter, washing out the vessel with a little distilled water, and pouring the washings over the precipitate. When the precipitate adheres to the glass, so that it cannot be removed by the glass rod, you must rub it off with a clean feather, or with the end of your fore-finger, which must previously be washed very clean, and the precipitate on which must be carefully washed off by means of the edulcorator, an instrument of which I shall speak presently.

When the liquor has all run through the filter, and left the precipitate in a comparatively dry state, it is still necessary to free the latter from the portion of the solution with which, being a very spongy mass, it must necessarily remain impregnated. You effect this by washing it with distilled water, by the help of an *edulcorator*, or washing-bottle.

The edulcorator is a bottle of the description represented by the figure in page 11. Its mouth is closed by a cork, through which a short piece of strong glass tube is passed. The cork must fit the bottle very tight, and the external orifice of the glass tube must be very small, never exceeding the fortieth of an inch in diameter. The bottle should be rather more than half full of distilled water. If you hold the edulcorator with the cork downwards, and then put the point into your mouth, and blow air into the bottle, the water, upon your removing the point from your mouth, will, for a few moments, be expelled from the edulcorator with considerable force. It passes out in a fine stream, which can be directed upon the precipitate in the filter so as to stir it up and wash it with great ease and effect. Towards the end of the edulcoration, the jet of water should be directed towards the edges of the filter, and not upon the precipitate itself, by which means the precipitate is washed down to the bottom of the filter, and brought into a small compass. Precipitates of a gelatinous consistence require much washing. The jet of water is sometimes destitute of sufficient force to stir them up. In this case you may stir them with a small glass rod with a round end; but you must be exceedingly careful not to force the rod through the filter, otherwise the filtration will have to be repeated.



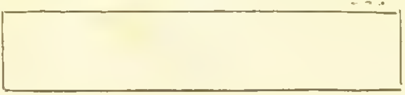
The edulcoration must be continued until the precipitate is completely freed from the solution in which it was produced. This is the case when the liquid which drops from the neck of the funnel consists of pure water alone. You take a drop of liquid from the neck of the funnel upon a bright piece of platinum foil, and evaporate the liquid to dryness. If it leaves no residue it is pure water; if it leaves a stain, it still contains fixed matters, and the edulcoration must be continued. If the solution which runs through the filter contains sulphuric acid, muriatic acid, barytes, silver, or any other substance for which you possess a re-agent which acts as a very delicate precipitant, you may collect a drop or two of the liquid at the neck of the funnel, and test it with that particular re-agent. In this case you continue the edulcoration until the washings give no precipitate with the said re-agent.

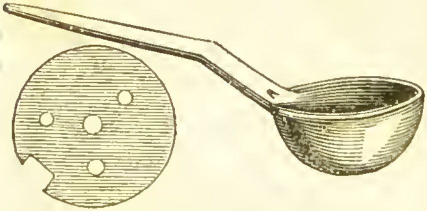
It is scarcely necessary to inform you, that the neck of the funnel must never be allowed to dip into the filtered solution, for, otherwise, the liquor which runs from it can never be collected for testing.

Solution of Precipitates.—It is frequently necessary to re-dissolve the solid compounds produced by precipitation, in order to subject them to the action of additional tests. The precipitates are gently dried on the filter till they acquire the consistence of soft dough, and are then removed from the paper, and put into the liquid in which it is intended to dissolve them. But when the precipitate is very small in bulk, or sticks very closely to the filter, or is much spread over the surface of the paper, it is often advisable not to attempt to separate it from the filter, but to expose it, paper and all, to the action of the solvent. It very seldom happens that the constituents of the paper can do any mischief. When the liquid has dissolved the precipitate, you filter the solution through a new filter, and thus separate the original filter from the solution produced by the precipitate. Another method of separating a precipitate from a filter is as follows:—You take the funnel which contains the filter and precipitate, still in a moist state, and fix it over the vessel which is to contain the solution produced by dissolving the precipitate. You then take the liquid which is to be employed as the solvent, and after making it boiling hot, if necessary, you pour it over the precipitate in the funnel. In passing through the filter it dissolves the precipitate, and separates it from the paper very neatly. In this manner peroxide of iron, which has been precipitated by ammonia, may be dissolved by hot muriatic acid.

Ignition.—It is often necessary to make a substance red hot, either to free it from water or to decompose and char any organic substances which it may contain. Sometimes the ignition may be performed in a Hessian crucible, or for want of that, in a clean tobacco-pipe. But in most cases, the vessel in which a substance is exposed to ignition, is best when made of platinum; only, it is necessary to remember, that platinum vessels can never be employed when reguline metals, such as uncombined lead or copper are likely to be produced by the ignition, or where free chlorine is likely to be disengaged during the experiment; as, for example, when muriatic acid comes into contact with the peroxides of manganese or of lead.

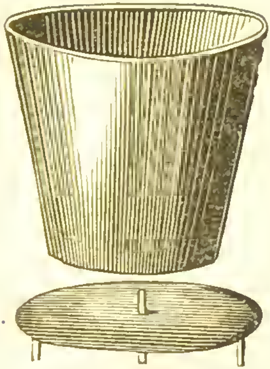
The simplest form of an instrument for ignition is a piece of platinum foil, as thick as stout writing paper, and as large as the figure in the margin. The substance to be ignited is placed on one end of the foil, which is previously hollowed a little by the pressure of a finger, and is then exposed to the flame of a spirit-lamp or the action of the blowpipe.





When a substance is to be heated with fluxes, or when the quantity is somewhat considerable, it is convenient to ignite it in a little platinum spoon the size of the above figure. This spoon should be stuck into a tobacco-pipe handle, and should be provided with a cover. The latter ought to have three pegs below to keep it in its proper place on the spoon, and a centre peg on the upper side to serve for a handle. For certain experiments, a silver spoon of this form is convenient; but though such a spoon is much cheaper than one formed of platinum, it is too fusible and too easily acted upon by acids, to be generally useful. The cost of a platinum spoon of this description is eight or ten shillings.

An instrument more generally useful than the platinum



spoon, but at the same time more expensive, is the platinum crucible, which with its platinum cover, is represented in the margin. The cost of a vessel of this size is about £2. But those who wish to make experiments on qualitative analysis only, can have one made smaller and slighter for about £1. I have indeed seen them without covers at ten shillings, but they were too slight to wear well. If any person wishes to practise analytical chemistry extensively, he cannot do without a platinum crucible as large as the above figure.

In many cases, where metallic crucibles are objectionable, it is proper to employ crucibles of porcelain or Wedgewood's ware. These may be procured of various sizes; but those which are an inch or an inch and a half in diameter are most useful in qualitative analysis. They are furnished with covers like the platinum crucible. It is impossible to heat a substance so powerfully in a porcelain as in a platinum crucible, particularly over a lamp.

Substances of small bulk may be ignited in the platinum capsule (p. 13).

Fusion.—The act of converting a solid into a fluid by means of heat. This operation is performed in the same vessels, in the same manner, and with the same precautions as "Ignition."

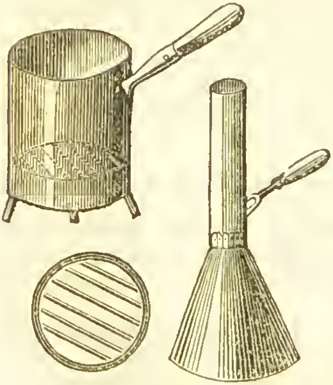
Reduction.—The operations by which metals are restored to their metallic state, after having been deprived of it, either by combustion, as the metallic oxides, or by the union of some heterogeneous matters which disguise them as fulminating gold, horn silver, cinnabar, and other compounds of the same kind. Reduction is also called *revivification.* The operation is performed in crucibles, by the aid of heat, and with the addition of certain substances, which act chemically upon the body to be reduced.

Fluxes are substances employed to assist the fusion of minerals. *Crude flux* is a mixture of nitre and tartar, which is put into the crucible with the mineral intended to be used.

White flux is formed by projecting a mixture of equal parts of nitre and tartar, by moderate portions at a time, into an ignited crucible. It is potass in tolerable purity. *Black flux* differs from white flux (both being made in the same manner) in the proportion of its ingredient. In this, the weight of the tartar is double that of the nitre. *Microcosmic Salts* is procured, by mixing equal parts of phosphate of soda and phosphate of ammonia in solution, and then crystallising. A slight excess of ammonia is useful.

APPLICATION OF HEAT.

The method of applying heat differs according to the intensity of the heat required, to the bulk of the object to be heated, and the length of time during which the heat is to be sustained. It can be conveniently applied by means of a small spirit-lamp, a large spirit-lamp, an oil-lamp, a charcoal fire, or a blowpipe.



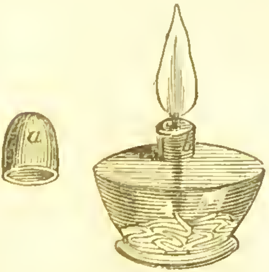
If you want to ignite a large crucible, or to evaporate a large bulk of liquid it is best to employ a charcoal fire. The figure represents a furnace of iron-plate, constructed on the following scale:—

———————— 1 Foot.

A grate (represented by the lower figure on the left hand) is fixed near the bottom of the furnace, and the whole is supported on three short feet to permit air to enter below the grate. The inner side of the furnace may be lined with a coat of fire-clay half an inch thick, to keep the heat from escaping too freely. The funnel-shaped vessel is formed of iron-plate, and serves, when placed over the furnace, to make the fire burn fiercely. You should be provided with a round flat grating made of iron wire, with meshes $\frac{1}{4}$ of an inch in diameter, which on being placed upon the furnace serves to support flasks and capsules which may be exposed to the fire. You should also possess several round flat pieces of iron plate rather larger than the top of the furnace, with holes in the middle from 1½ inch to 5 inches in diameter, adapted to receive capsules and other vessels to be heated.

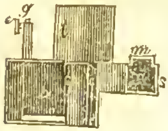
When you wish to have a *sand-bath*, place upon the above furnace a pan of plate-iron, 12 inches square and 2 inches deep, filled with washed and sifted sea-sand. A platform of bricks should be put under the furnace when it is placed on a table or on the floor of a room; and the bricks should be covered with a piece of plate-iron. A chimney must pass up through the sand-pan, or a couple of iron bars be placed between the pan and the top of the furnace, otherwise the fire will not burn well.

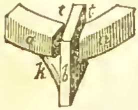
When you wish to apply a moderate heat, to evaporate a solution of small bulk, to heat the contents of a tube, or to ignite a small crucible, you make use of the small spirit-lamp. This consists of a short strong glass bottle, the neck of which contains a brass tube, holding a cotton wick. The bottle should be nearly full of spirits of wine of a moderate strength. If highly rectified, it is too dear; if too much diluted, its flame is less powerful than it ought to be. Spirits of wine burns without smoke, so that a tube does not become soiled when heated in the flame of such a lamp. This is of considerable importance, for when a tube becomes coated with soot, as it does when you hold it over a candle, you cannot see what takes place within it during an operation. When you are going to heat the contents of a glass tube, you must approach the tube to the flame very gradually, particularly if the bottom be thick. If you plunge it suddenly into the flame, the glass breaks and your preparation runs out.—The lamp should be furnished with a glass cap fitted to it by grinding, to prevent the evaporation of the spirit, when the lamp is not in use. When you want to put out the flame, you clap on this cap as an extinguisher.

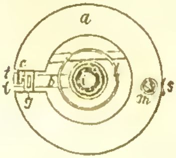


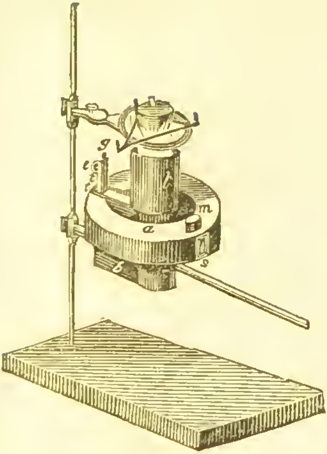
If you think a glass lamp, which may cost four or five shillings, to be too expensive, you may employ a small tin lamp, furnished with a tin cover, or you can construct a spirit-lamp by putting a tin-plate tube or a short glass tube through the cork of a small broad bottle. You increase or diminish the power of the spirit-lamp, by making the wick thicker or thinner.

Experiments which require a great degree of heat, such as the ignition of refractory substances, demand the assistance of the spirit-lamp with circular wick or double current of air. This is one of the most indispensable instruments of the analytical chemist, for there are many accurate experiments which cannot be performed without it.—The wick *c* passes between two cylinders which are connected below by a horizontal plate, and it can be raised or depressed by means of the toothed wheel *e* and the toothed bar *g*. The lower end of the latter is connected with a cross-bar *o*, upon the end of which a ring is fastened, on which ring the wick is stuck. The cross-bar and toothed-rod work up and down in the box *b*. The box does not form part of the spirit-holder *a a*, as it does in the common lamps, but is separated from it by the open spaces *t t*, or at any rate by a partition on each side. The spirit passes from *a a* into *b* through the pipe *k*, which forms the only communication between the spirit-holder and the box which holds the wick. The object of this contrivance is to prevent the explosion which frequently takes place when the common spirit-lamps are inflamed, and which is owing to the inflammation of the mixture of atmospheric air and vapour of alcohol which forms in the spirit-holder *a a*. At *m* is an opening by which the spirit is poured into the lamp. This is afterwards closed by a cork. A piece of glass is cemented in the front of the lamp, at *s*, to afford an opportunity of readily ascertaining how much spirit the spirit-holder *a* contains. The lamp is provided with a copper chimney, *l*. By raising or depressing the wick, the flame is increased or diminished. The air is brought to the spirit, externally by the side, and internally by the canal *i*. The wick must be cut quite level, and must never remain in a charred state. When a lamp is constructed in this manner, and







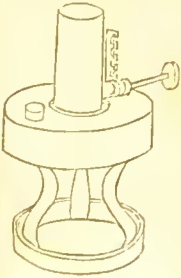


according to the following scale:—

———————— 1 Foot,

it affords heat sufficient to fuse three hundred and eighty grains of carbonate of soda in about fifteen minutes, supposing the salt to be contained in a platinum crucible of the weight of from 300 to 380 grains, and large enough to contain an equal weight of water. A lamp which is incapable of effecting the fusion of at least 180 grains of carbonate of soda, though useful in a great many experiments, is not powerful enough to be generally employed in the analysis of minerals. The experimental chemist ought to possess two lamps of this description; one for fusing, and another for other experiments. In the latter case, the rods which support the lamp may be strong, but for the other lamp, the rods must be made as thin as possible, in order that they may not carry away too much of the heat.

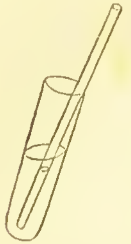
In France and Germany, spirits of wine is very cheap, but in England it is very dear, in consequence of the excise duty. This is an unfortunate restriction upon the industrious pursuit of analytical chemistry by English students. Many who have more zeal than money, attempt to perform imperfectly with oil-lamps what foreign chemists perform perfectly with spirit-lamps. This must continue to be the case until an alteration takes place in the excise laws. There is no doubt that the progress of experimental chemistry is retarded in this country by the simple circumstance just alluded to.



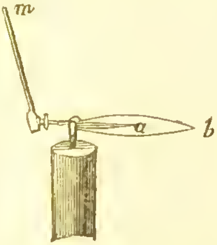
The annexed figure represents a copper chemical lamp, with a copper chimney. The price of such a lamp is about 10*s*. 6*d*.

When oil-lamps are employed, they should be filled with the clearest oil. Pyro-acetic spirit is coming into use as a fuel for chemical lamps. It is superior to oil. Its cost is nine shillings per gallon.

Oftentimes a moderate degree of heat is required to be kept up for a considerable time. In this case, the chemist employs a *water bath.* Let water boil in a tin or copper vessel over a lamp or fire, and expose the vessel which is to be heated either to the hot water or the steam, by placing it through a hole in the cover of the water-pot, or by some other contrivance. The annexed figure represents a miniature water-bath. The wide tube contains water supposed to be boiling over a lamp. The long narrow tube contains the subject of experiment, which in this position is subjected to the heat of boiling water as long as the heat and the supply of water is kept up.

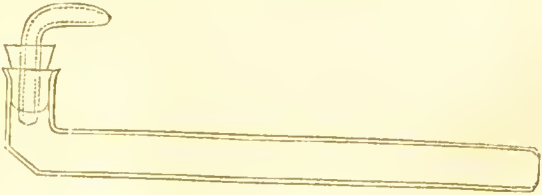


THE USE OF THE BLOWPIPE.—In many experiments, it is of great importance to be able to expose small substances to a very high temperature; in this case, it is necessary to employ the *blowpipe,* an instrument with which a current of air is blown into the flame of a lamp or candle. This gives one the power of producing in a moment, the most intense heat of a powerful furnace. You can easily perform with the help of this little instrument, the experiments which are necessary to determine the chemical nature of many different substances. You can produce any temperature up to a white heat.—Many advantages may be derived from the use of the blowpipe. Its smallness, which renders it suitable to the pocket, is no inconsiderable recommendation. The most expensive materials, and the minutest specimens of bodies, may be used in these experiments; and the whole process, instead of being carried on in an opaque vessel, is under the eye of the observer from beginning to end. It is true, that very little can be determined in this way concerning the quantities of products; but in most cases, a knowledge of the contents of any subject is a great acquisition, which is thus obtained in a very short time, and will, at all events, serve to show the best and least expensive way of conducting processes, with the same matters, in the larger way.



The blowpipe is a tube of brass, about six inches long, and one-fourth of an inch in diameter at one end. It tapers off to a fine point at the other end, where the orifice must be about the eightieth part of an inch in diameter. The point must be bent on one side, and the tube must be furnished with a cylindrical reservoir to hold the water which air, blown from the mouth, deposits in the tube. In looking at the figure, you are to suppose the point *m* to be in the mouth of an operator placed opposite to yourself.

If you do not possess a blowpipe of the above form, you may employ a common brass goldsmith's blowpipe, which costs sixpence; but it is much more convenient to have a blowpipe with a platinum point, for the common sorts soon become unfit for service. A very good and cheap blowpipe may be prepared as follows:—Take a glass tube, six inches long, three-eighths of an inch wide, and one-twelfth of an inch thick in the glass; bend an inch of it at one end at a right-angle, taking care to make the bend so carefully as not to obliterate the bore of the tube. The heat of a spirit-lamp is sufficient to soften the glass to be bent. Next take a piece of tube, two inches long, one-fourth of an inch thick, and one twelfth of an inch in the bore; turn round the point in the flame of a spirit-lamp, until the opening is contracted to a hole sufficiently small for the orifice of a blowpipe; bend the tube at a right-angle in the middle, and adapt the other end of it, by means of a cork, to the



bent end of the larger tube. The point should be withdrawn from the flame and suffered to cool very gradually, that it may be well annealed. It is otherwise liable to split when presented to the flame afterwards as a blowpipe.

There is an artifice in the blowing through this pipe, which is more difficult to describe than to acquire. The effect intended to be produced is a continual stream of air for many minutes, if necessary, without ceasing. This is done by applying the tongue to the roof of the mouth, so as to interrupt the communication between the mouth and the passage of the nostrils; by which means the operator is at liberty to breathe through the nostrils, at the same time that, by the muscles of the lips and cheeks, he forces a continual stream of air from the anterior part of the mouth, through the blowpipe. When the mouth begins to be empty, it is replenished by the lungs in an instant, while the tongue is withdrawn from the roof of the mouth, and replaced again in the same manner as in pronouncing the monosyllable *tut*. In this way the stream may be continued for a long time without any fatigue, if the flame be not urged too impetuously, and even in this case, no other fatigue is felt, than that of the muscles of the lips.

A candle, with a thicker wick than they are generally used with, may be conveniently employed for occasional experiments. It should be snuffed rather short, and the wick turned on one side towards the object, so that a part of it may lie horizontally. The stream of air must be blown along this horizontal part, as near as may be without striking the wick. If the flame be ragged and irregular, it is a proof that the hole is not round or smooth; and if the flame have a cavity through it, the aperture of the pipe is too large. When the hole is of a proper figure and duly proportioned, the flame consists of a neat luminous blue cone, surrounded by another flame of a more faint and indistinct appearance. The strongest heat is at the point of the inner flame.

Considerable disadvantages, however, attend the use of candles. The difficulty of getting good ones, or such as have thick wicks, is frequently great. By far the best flame that can be employed, is that of a lamp supplied with olive oil.—The following figure represents the blowpipe-lamp which is recommended by Berzelius. It consists of a tin-

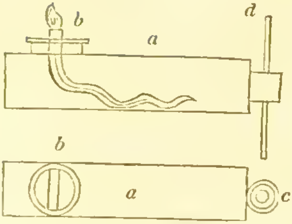


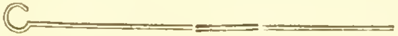
plate cylinder, one inch wide and four inches long (*a*). At *b* is an opening, three-quarters of an inch long, for holding a flat lampwick. This opening can be closed by a screw-cap. *c* represents a little cylinder, fastened to the end of the lamp. This cylinder holds a perforated cork, which admits the rod (*d*) of a little retort-stand, (such as represented at page 14.) The lamp can be raised on this rod to any height the operator finds convenient.—The stream of air is blown along the top of the flat wick, and not across it. The flame is powerful, and at the same time much under the command of the operator, who, by putting the blowpipe into the flame, reduces the volume of the jet thrown out by the blast. The blowpipe experiments which relate to the colours that various substances communicate to flame, require very little light.

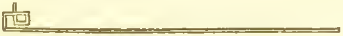
When you are going to operate, you sit with the lighted lamp before you, and nearly level with your mouth. You hold the charcoal which is to serve for a support in your left hand, and put upon the end of it the substance to be heated. You then take the blowpipe in your right hand, and putting the upper end into your mouth, you approach the point to the flame of the lamp, and direct a jet of fire upon the substance under examination. (See the figure at page 66.)

You examine, by means of the blowpipe, whether substances are volatile or not; whether they become decomposed by heat or not; what are the products of their decomposition; whether they are fusible or not; what phenomena they exhibit when fused with other substances; and how they act when heated so as to be oxidised or disoxidised. The disoxidation depends upon the part of the flame in which the substances are heated. In the blowpipe flame there are two sorts of combustion; in the interior by means of the air which is blown into the flame by the blowpipe; and at the exterior, where the flame acts on the atmosphere. Between these two places there exists a mass of combustible gases which has a very high temperature.

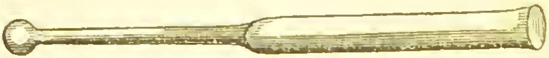
If you hold in these gases, that is to say, in that part of the flame situated between *a* and *b* (page 41), any substance which contains oxygen, such as oxide of lead or oxide of copper, the oxygen of the oxides combines with the combustible gases, and the metal fuses and appears in the reguline state. On the other hand, when any substances are held without the flame, and a little beyond the point *b*, they are strongly heated, and if oxidable, combine with the oxygen of the air, and produce oxides; a piece of tin, for example, if held in this situation, immediately produces a white oxide.

The fluxes with which metallic oxides are commonly fused are *borax*, *carbonate of soda*, and *microcosmic salt*, or double phosphate of soda and ammonia, which three salts should be kept ready pounded for use. They may be preserved in pill-boxes or short bottles. When borax is employed, the flux and assay are commonly heated together on a piece of platinum wire, bent at one end into a ring. The subjoined figure exhibits the size and thickness of the wire. When the other two fluxes are employed, the support is commonly a piece of well burned charcoal. The blowpipe experiment for the detection of chlorine, requires the use of a copper wire of the annexed figure. The wire must be of the thinnest kind. Brass wire may be used for the same experiment.



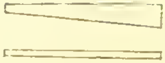


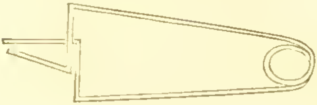
In many small experiments, when a volatile substance is to be separated from other matters by sublimation, but to be retained for examination, a tube of this form is employed.



The sublimed matter condenses on the cold part of the tube, after escaping from the heated bulb.

Platinum foil, cut into the size shown at page 34, is a useful support for blowpipe experiments; and a pair of steel or brass forceps, with narrow and thin platinum points, are indispensably necessary, when minerals and most other substances are to be heated without addition. The points of





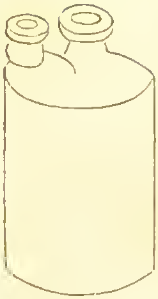
platinum forceps are made of flattened platinum wire, in pieces of this size, and as thin as a common playing card. A cheap pair of platinum forceps can be made of two such points rivetted to the two points of an iron wire, bent into the form of the annexed figure.—But I refer you for detailed instructions respecting the use of the blowpipe to "*A Practical Treatise on the Use of the Blowpipe in Chemical and Mineral Analysis, by* JOHN GRIFFIN," and to "*The Art of Glass Blowing*," which forms Vol. I. of the "*Polytechnic Library.*"

A few experiments, illustrating the use of the blowpipe in analytical inquiries, will be given in a subsequent section of this work.

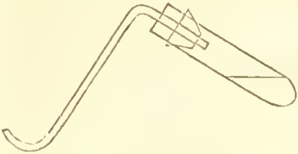
MANAGEMENT OF GASES.

FOR performing experiments on gases, many articles of apparatus, not hitherto described, are necessary. These consist, partly of vessels for containing the materials which afford the gases, and partly of vessels adapted to contain the gases and submit them to experiments. Some gases are procurable by the mere mixture of the substances, which, upon combining, evolve them; but others cannot be obtained without submitting the materials to heat. For these different modes of proceeding, it is requisite to employ a variety of vessels.

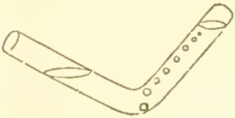
For the gases which are prepared with the aid of heat, you may employ a retort, a Florence flask, or any other glass vessel, the bottom of which is thin enough to bear the application of heat without cracking. The same vessels may be employed for the preparation of such gases as do not require the aid of heat; but in general the latter can be more readily prepared in vessels which stand steady upon the table without support. Such a vessel is the *Woulfe's bottle*, exhibited by the



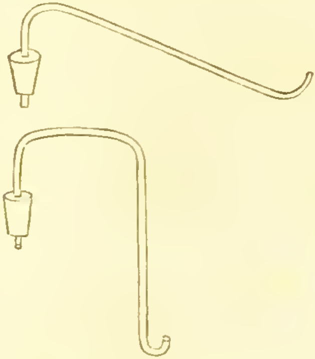
annexed figure. It is simply a broad short glass bottle, furnished with two necks. When very small quantities of gases are to be prepared, the operations may take place in small bottles, of the description figured in page 11, or in little matrasses and retorts constructed of glass tubes (pages 11, 12). Oxygen gas is sometimes prepared in an iron retort, and hydro-fluoric acid gas in a platinum or leaden retort; but glass is the material which is generally made use of for retorts.



A very small quantity of a gas can also be prepared in a tube retort, such as is figured in the margin. This consists of a tube like figure *a*, page 11, but shorter and wider; and its mouth is stopped by a cork, through which a tube for conducting gas (see page 19) is passed, the tube in this case being very small. And when you need to ascertain the nature of a gas given out in a particular operation, a tube like the following may be employed. You perceive that this tube bulges out a little at the elbow, and that the part which bulges out is below the sealed end of the tube. If you put some muriatic acid in such a tube, then hold it in the position shown by the figure, and drop a bit of marble into it, the marble will descend to the bulge, where it will be decomposed by the muriatic acid, and a quantity of carbonic acid gas will be produced, all of which will ascend in bubbles to the sealed end of the tube, and none will escape. In this case, a single tube acts the double part of a retort and a receiver. This apparatus is often more useful, when the sealed end is turned over a little, made into a mouth, and provided with a stopper.

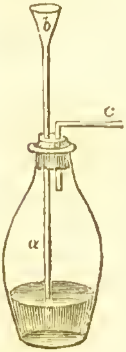


Put into the gas-bottle the materials whose reaction is to produce the desired gas. Break the solid part into small pieces to facilitate chemical action; put in the powder through a warm funnel, and pour in the liquid through a funnel, to avoid soiling the neck of the bottle. If your bottle has two necks, one of them should be provided with a ground glass stopper, or a cork that fits close. The neck through which the gas is to escape, should be closed by a cork provided with a glass gas-tube, bent more or less, according to the distance and shape of the vessels into which the gas is to be conveyed. The sort of tubes necessary to be employed in these experiments, has been spoken of at page 19.



When the conducting tube is fixed into the bottle, apply your mouth to the open end of the tube, and *suck* strongly: you will thus ascertain whether or not the joinings of the apparatus are completely air-tight, which they must be made to be. You will, of course, make this trial when the bottle is empty, and not while a gas is being generated within it. If the joinings are not air-tight, they may sometimes be rendered so by applying a small quantity of a lute; but it is better to fit new and sound corks on the tubes. The corks should be first perforated by a red hot iron wire, one-eighth of an inch thick, and the hole should be enlarged by a rat's-tail file. It requires a little practice to enable you to bore a hole perfectly cylindrical.

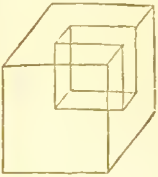
The materials put into a bottle to produce a gas, must never exceed in bulk the third or fourth part of the capacity of the bottle, otherwise they are apt to boil over when the action comes to be powerful, and the disengagement of gas rapid. When the materials consist of a liquid and a fine powder, the liquid should be put into the vessel first, and the powder afterwards, and the two should be carefully mixed by shaking the vessel. You must take care not to respire an atmosphere contaminated by deleterious gases. Sulphuretted hydrogen gas is a particularly powerful poison, and it is fortunate that its noisome odour gives timely notice of its presence. Chlorine gas is exceedingly difficult to breathe, but it is not so injurious as the preceding. Arseniuretted hydrogen gas is very deadly; a celebrated German chemist was killed by smelling it. Carbonic acid gas occasions suffocation if mixed with the air in large proportions. Experiments with gases ought not to be made in a close apartment, but either under a large chimney or in the open air. The first portion of gas, of whatever kind it may be, evolved from the vessel in which it is formed, is always contaminated with the common air, with which the vessel was filled at the beginning of the operation. A quantity of the first air received, equal to twice the capacity of the vessel in bulk, must, therefore, in order to avoid accidents and failures, be thrown away.



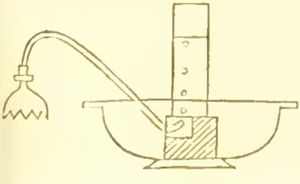
It is sometimes necessary, during a distillation, to give a fresh supply of acid to the mixture in the gas bottle. To be enabled to do this, without interrupting the process, it is proper to provide the neck of the bottle with a cork containing two holes, instead of one. You fix into one of these holes the tube which is to convey the gas, and into the other a tube with a small funnel (*b*) at its upper end, and with a neck (*a*), so long that it dips into the liquid contained in the gas-bottle. It is by means of this funnel and tube that you are to introduce the acid at all times when it is required.

When the gas-bottle is to be exposed to heat, it must be held over the lamp by one of the supports, or retort stands, described at page 14.

Collecting of Gases.—When glass jars, or any other vessels, open only at one end, are plunged under water, and inverted after they are filled, they will remain full, notwithstanding their being raised out of the water, provided their mouths be kept immersed; for, in this case, the water in the jar is sustained by the pressure of the atmosphere, in the same manner as mercury in a barometer. It may without difficulty be imagined, that if common air, or any other fluid resembling common air in lightness and elasticity, be suffered to enter these vessels, it will rise to the upper part, and the water will subside. If a bottle, or cup, or any other vessel, in that state which is usually called empty, though in reality full—of *air*, be plunged into the water with its mouth downwards, scarcely any water will enter, because its entrance is opposed by the elasticity of the included air; but if, while the vessel is immersed, its mouth be turned upwards, the air will rise in bubbles to the surface of the water, leaving the water to occupy its place in the vessel. Suppose this operation to be performed under one of the jars which are filled with water, the air will ascend as before; but, instead of escaping, it will be detained in the upper part of the jar. In this manner, therefore, we see, that air may be emptied out of one vessel into another by an inverted pouring. Just in this manner are gases collected in vessels placed in what is termed a pneumatic trough: the jars which are to receive certain elastic fluids, are filled with water, and placed, mouth downward, upon a shelf, and the necks of retorts, and ends of tubes, from which gases are evolved, are directed below holes made in the shelf under the jars; then the gases, as they issue forth, rise in bubbles through the water, enter the jars, driving thence the water, and occuping its place. When, therefore, the jars are thus emptied of water, they are filled with gas.

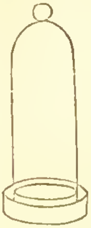


The pneumatic trough is simply a wooden tub, or vessel of tin-plate, filled to within two inches of its top with water. It should be provided with a shelf, placed an inch below the surface of the water, or with a wooden block, cut into the form shown by the figure, and plugged with lead to make it sink in water. When you wish to fill a jar with gas, you place it full of water, in an inverted position, over the hole cut in the block, and you direct the point of the tube whence



the gas is to issue into this same hole. The water in the tub must rise about an inch above the top of the block. The size or form of the trough is quite immaterial. A wash-hand basin answers the purpose very well. The annexed figure exhibits the mode of putting together a pneumatic apparatus, such as has been here described.

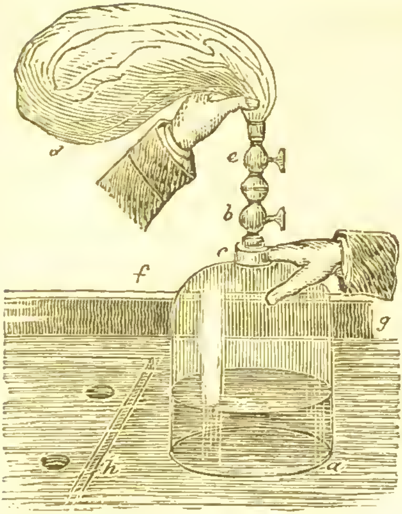
Any kind of glass vessel can be employed as a *receiver* for gases; in the last figure, a plain cylinder is represented; but particular experiments require vessels of a particular size and form. This will be adverted to when necessary. Lecturers on chemistry generally employ a metallic gas-holder to contain large quantities of oxygen or hydrogen gas. But this apparatus is useless to a student. If at any time a large quantity of oxygen gas is prepared, it may be put into green glass wine bottles, and corked up. Each bottle should be placed aside, bottom upwards, with the mouth plunged in a little pot of water. The gas will not escape.



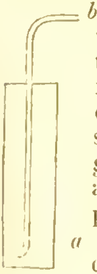
When a bottle has been filled with gas in the manner described above, it may be corked under water, and then removed from the trough. If a jar with a wide mouth has been filled, you must fill a tea saucer, a soup plate, or other shallow vessel, with water, and slide the filled jar from the block into the soup plate, the small quantity of water contained in which will prevent the escape of the gas from the jar.

When you want to transfer gas from a wide-mouthed into a narrow-mouthed vessel, you must hold a funnel in the mouth of the latter. All transfers of gas must be effected under water, and, as it has been expressed above, by an inverted pouring. As water emptied in air descends, so air emptied in water ascends. This is the principle upon which the decantation of gases depends.

Filling of Bladders with Gases. As it is frequently necessary to fill bladders with gases, I shall describe the method of doing it. The following figure represents the apparatus employed for this purpose. *a* is a glass receiver, supposed to contain gas; it is open at the bottom, and provided with a brass cap and stop-cock at the top. A vessel six inches in diameter and eight inches high, is sufficiently large for a student's experiments. *d* is a bladder, to the mouth of which a stop-cock is fastened by means of a ferrule. *f* is the side of a pneumatic trough; *h* is the shelf, *g* the level of the water, *e* and *b* are the stop-cocks of the bladder and receiver, by which the two are connected.

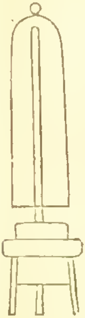


Moisten the bladder with water to render it flexible, squeeze it close to expel the common air from it, then shut the stop-cock *e*, and screw it to the stop-cock *b*, on the top of the receiver, which is supposed to be placed upon the shelf in the trough. Next, open both the stop-cocks, hold the apparatus in the manner shown by the figure, gently slide the receiver off the shelf, and press it down into the water; the gas will soon enter and fill the bladder, being forced through the opening by the upward pressure of the water. The stop cocks are then to be closed, the receiver replaced on the shelf, and the two vessels disunited. Previously to undertaking experiments on gas, the young student should accustom himself to the dexterous management of gases, by performing the processes of decantation, filling of bladders, &c. with common air.



Many kinds of gas are condensed by water, and cannot therefore be collected in jars placed in the water-trough described above. For retaining gases of this kind, chemists generally employ a trough of mercury instead of water; but this is a mode of collecting gases by far too expensive and troublesome for the adoption of young students. Several gases, which are either lighter or heavier than atmospheric air, may be collected in tolerable purity, and without the aid of any trough, as follows:

To Collect Heavy Gases. Let *a* represent a clean dry glass cylinder, and *b* the tube which brings the gas to be collected, from the vessel in which it is produced. As the heavy gas issues from the tube, it settles at the bottom of the cylinder, and forces the lighter atmospheric air to ascend and flow out of the top of the vessel. Thus the heavy gas gradually displaces the air, and soon fills the cylinder. Chlorine, muriatic acid, sulphurous acid, and carbonic acid gases can all be collected in this manner. You readily ascertain when the vessel is full of chlorine gas, in consequence of the yellow colour of that gas. Muriatic acid gas flows over and produces fumes in the air. You test the fullness of vessels containing carbonic and sulphurous acid gas, by putting a lighted match near the opening. If the light goes out, the gases have risen to the top. You must allow a little gas to flow over, to ensure the expulsion of the common air.



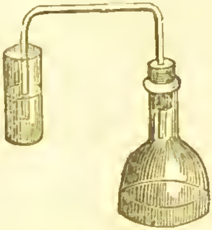
To Collect Light Gases. Gases that are lighter than atmospheric air, such, for example, as ammonia, can be collected by a process which is the reverse of the preceding, and which is pictured in the margin. A tube passes *upwards* to the top of a receiver, the light gas escapes from the tube, settles at the top of the receiver, and depresses and drives away the whole of the atmospheric air. By holding a slip of wet turmeric paper to the mouth of the jar, you easily learn when it is full of ammonia, because turmeric is coloured red by ammonia.

When gases are thus collected, they are to be secured in the bottles by the insertion of greased glass stoppers, or in the cylinders by the application of greased glass plates. But the gases thus collected ought to be employed immediately.

Measurement of Gases. Gases are measured by being introduced, either over water or mercury, into jars or tubes graduated into parts of equal capacity. The accurate measurement of gases cannot be effected without taking a variety of precautions.

Weighing of Gases. To ascertain the specific gravity of gases, it is necessary to have good apparatus and great skill in experimenting. A glass globe, provided with a stopcock, is weighed. It is then exhausted of air by an air-pump, and weighed empty. It is afterwards filled with gas, and again weighed. The weight of the common air, compared with the weight of the gas, shows the specific gravity of the latter.

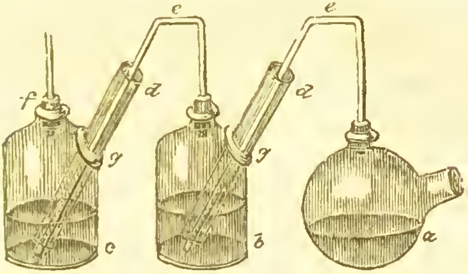
Solutions of Gases.—When gases are prepared for analytical experiments, they are generally made to act upon liquids. In this case, the extreme end of the conducting-tube is made to dip into the liquid which is to be exposed to the action of the gas. In proportion as the gas is forced from the flask in which it is generated, it passes into the liquid at the end of the tube, and is there absorbed. The liquid to be acted on by the gas, may be contained either in a cylindrical solution-jar (page 10), or in a bottle provided with a glass stopper. The latter is often made use of with advantage when the liquid is to be completely saturated with the gas. When the gas has been passed for some time into the liquid, you withdraw the bottle from the tube, put in the stopper, and shake the bottle. If, upon withdrawing the stopper, there is a rush of air into the bottle, the liquid is still unsaturated; if, on the contrary, there is no rush of air, and the bottle smells strongly of the gas, then the liquid is near the point of saturation.



Experiments of this description are liable to a variety of accidents, unless they are performed with a suitable degree of care. I shall mention these accidents, and the means of preventing them.—1. If the mixture which disengages the gas is thick, and the effervescence so powerful as to force a portion of the mixture into the tube, the bottle may burst, in consequence of the inability of the gas to escape through the obstructed tube. To prevent this, you must, as before directed, put but a small quantity of the mixture into the bottle, and you must keep the action moderate and regular by a suitable application of heat.—2. If the mixture boils over into the liquid which is exposed to the action of the gas, the whole operation is spoiled. To prevent this, you must take notice when the mixture rises up in the bottle, and either remove the lamp from below the bottle, or the liquid from the mouth of the conducting-tube.—3. If the disengagement of gas from the mixture happens to slacken, in consequence of the application of too low a degree of heat, or of some other cause, a vacuum is produced in the bottle, and the liquid which is exposed to the gas is forced through the gas-tube into the bottle. In this case, the operation is ruined, the liquid lost, and very often the bottle broken. To prevent this, you must keep the tube dipped but a little way into the liquid, so that, when you observe the liquid begin to mount into the tube, you have only to lower the vessel a little, so as to bring the liquid below the mouth of the tube, to avoid the above effect. You must also take care to heat the gas-bottle with a steady and regular fire. Remember, that an operation of this sort must never be neglected. You must watch the progress of a distillation as a cat watches a mouse. Your eyes must never be off the vessels, and your hands must never be occupied with any other business than that belonging to the process. A single moment of inattention may ruin the result of many days' labour.

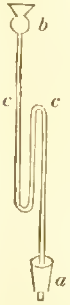
The eagerness with which the solution and the mixture in the gas-bottle encroach upon each other's domain are such, that it is advisable, in all experiments of importance, to place an intermediate vessel between the other two. This may be a Woulfe's bottle, with two necks, or a receiver, similar to the one represented at page 18. The three bottles are connected together by corks and glass tubes. In this case, the solution is less liable to be spoiled, and the gas-bottle less liable to be broken, than when the solution and the bottle are connected only by a single tube.

WOULFE'S APPARATUS FOR COMPOUND DISTILLATION.—In several cases of *distillation*, the substance raised is partly a condensable fluid and partly a gas, which gas is incondensable by itself, but capable of being condensed by being transmitted through a liquid. The apparatus required by a process, in which this double purpose is effected, is represented by the following figure, and is commonly termed Woulfe's apparatus. It is a series of receivers, connected together in a particular manner, and more or less in number, as the case may require. The distilling vessel made use of, is the *retort* (page 18), into the tubulure of which, instead of a glass stopple, is inserted the safety-tube, of which a description is given below. The first receiver (*a*) is joined to the retort, and has a right-angled glass tube,



open at both ends, fixed into its tubulure. *b*, the second receiver, is a bottle which, besides its usual neck at the top, has an opening just at the place where its sides fall in to form the top: into this opening a glass tube is fixed diagonally, and the juncture is secured by the application of a lute. The lower end of this tube must be about an inch from the bottom of the receiver. *c* is in every respect the same as *b*. The openings spoken of are at *g g*, and the tubes fixed in them are shown by *d d*. The small tube *e*, which rises from the first receiver, passes down the diagonal tube in the second receiver; and another small tube, likewise marked *e*, rising from and luted in the neck of the second receiver, passes down the diagonal tube in the third receiver. If there were more receivers, they would be like *b* and *c*, and would be connected in the same manner. The lower ends of the tubes *e e* must project as far beyond the ends of the tubes *d d*, as they can do without touching the bottom of the bottles. The liquids by which the gas is to be absorbed are put into the second, and subsequent receivers, each being filled two-thirds full. The nature of this liquid is regulated by the nature of the gas to be absorbed, or by that of the solution intended to be produced. For gases that are rapidly absorbed by water, such as sulphurous acid, muriatic acid, &c., distilled water is made use of; for other gases, the carbonic acid, for instance, solution of caustic potass is employed. In general, it is advisable to put water into the second receiver, and the alcaline solution into the third; the *first* receiver (*a*) is always left empty.

The materials being introduced into the retort, the arrangements completed, and the joints secured by lutes, the distillation is begun. The condensable vapour collects in a liquid form in the receiver *a*, which is kept cool by being placed in water, or by having wet cloths applied to it. In the meantime, the evolved gas passes through the bent tube *e*, into the water contained in *b*, which continues to absorb it, if it is a gas absorbable by water, till it is saturated. When saturation takes place, or when no absorption ensues, the gas bubbles up through the water, passes through the second pipe *e*, and enters the receiver *c*. And so the process continues till the liquids in all the bottles are saturated; and then, if any gas continues to be produced, it escapes through the neck *f* of the last receiver. Should it be required to preserve this overplus gas, it may be conducted into a receiver placed in the pneumatic trough, by fitting into the neck *f* the bent tube figured at page 47.



It will be now proper to point out the use of the tube of safety, figured in the margin, and of the wide diagonically-fixed tubes *d d*. Supposing the retort to be closed by a stopple as usual; and supposing the bottles to be destitute of those tubes, and consequently that *e e* were luted into the receivers at *g g*, the process would be then liable to be interrupted by an accident: for if, in consequence of the irregularity of the heat, or other circumstances, a vacuum should be produced in the retort, by the re-absorption of gas, the liquids in the different receivers, being acted upon by the pressure of the atmosphere at *f*, would rush from one into another to supply that vacuum, and by such a mixture of products the whole experiment would be spoiled. If, on the contrary, gas were to be evolved faster than it could be absorbed by the different liquids, or than it could escape at *f*, the apparatus might burst, with considerable danger to the operator. Should the operator close *f* as well as all the other places, then the apparatus would be destroyed, if either absorption or expansion took place; for, in the one case, the external air would press the vessels till they broke, and in the other, the same effect would be produced by the elasticity of the gas confined within. Now, all these inconveniences are obviated by the employment of the different tubes. If an absorption takes place, when these tubes are fixed in the manner that has been described, the vacuum is instantly supplied by the external air, which rushes down the tubes *d d*, into the receivers, and down the tube of safety into the retort. The experiment being thus prevented from failing altogether, at the price of having a small portion of common air mixed with its products. On the other hand, no gas can escape, for any pressure within is instantly followed by a formation of a high column of liquid in the tubes *d d*, which resists the egress of the gas, as long as is consistent with safety.

The *Tube of Safety* is a glass tube of the size described at page 19, about sixteen inches in length, and bent as represented in the above figure. One end of this tube is fastened into a cork, and the other made into the form of a small funnel; *a* is the cork, *b* the funnel. In cases of distillation in which sudden absorption or expansion may take place in the retort, this utensil is fitted into the tubulure of the retort, and the bended part of it, *c c*, is filled with water. Then, if a vacuum happens to be produced in the retort, the external air forces its way through the tube to supply that vacuum; and, on the contrary, if expansion takes place, the elastic fluid gains room by forcing the whole water between *c c* up into the straight part of the tube under the funnel *b*. A number of other uses to which the safety-tube is applicable, are described in particular experiments.

LUTES are substances applied to the junctures of vessels used in distillation, to prevent the escape of vapours and gases. When vapours of watery liquors, and such others as are not corrosive, are to be confined, it is sufficient to surround the joining of the receiver to the retort with slips of wet bladder, or of linen, or paper, covered with flour paste, or mucilage of gum-arabic.—Soft cement is made of yellow wax melted with half its weight of turpentine and a little Venetian red to give it colour. It can be easily moulded by the fingers, and sticks well to dry substances.—When more penetrating and dissolving vapours are to be confined, the lute to be employed is of quick-lime slacked in the air, and beaten into a liquid paste with white of eggs. This must be applied on strips of linen; it is very convenient, as it easily dries, and becomes firm. This lute is very useful for joining broken china-ware.—For containing the vapour of acid, or highly-corrosive substances, *fat-lute* is made use of. This is formed by beating perfectly dry and finely-sifted tobacco-pipe clay, with painters' drying oil, in a mortar, to such a consistence that it may be moulded by the hand. To use it, it is rolled into cylinders of a convenient size, which are applied, by flattening them, to the joinings of the vessels, which must be quite dry, as the least moisture prevents the lute from adhering. The lute when applied is to be covered with slips of linen spread with the lime lute; which slips are to be fastened with pack thread.

The employment of thoroughly good corks often supersedes the use of lutes. It is easier to procure a good cork than to make a bad cork fit air-tight by luting.

LABORATORY.

I PROCEED now to give instructions for fitting up a *laboratory* upon a small scale, for the use of such as are about to commence the study of chemistry. I recommend the young student to buy only the most indispensable articles at first, and to increase his stock of apparatus by buying other articles when he wants them. Most people fall into the error of buying a great quantity of apparatus for which they have no use.

Provide a strong and level table, fronting a window in a room free from dust and disturbance, and where there are no children. Most chemical preparations are poisonous or hurtful; and all should be carefully kept out of the reach of those who might unwittingly do themselves harm. When you are obliged to work at a good table, it is prudent to employ an old tea-tray or a large flat tray formed of sheet-lead. This may save the mahogany from destruction.

Beware of the droppings of bottles! Remember that acids and alcalies can either alter the colour of clothes and furniture or burn holes in them. Take care how you pour liquors from bottles, and never let any run down the outside of the bottle. I will tell you how to prevent it. Suppose you want to pour a few drops of a liquid test from a bottle. Turn up the bottle so as to wet the stopper, then hold the bottle upright, withdraw the stopper, make with it a wet line from the opening of the mouth to the edge of the ring or flat piece that terminates the neck of the bottle, apply the side of the stopper to the end of this wet line, and bring the bottle slowly into a horizontal position. The liquor will then run down the stopper in drops, without dirtying the outside of the bottle. If you attempt to pour a single drop from a bottle without this precaution, you may chance to pour out half a bottleful. This method of pouring is further explained in the article on *decantation*, at page 26. You should, however, always have some tow or old rags at hand, to wipe up any thing that is spilled accidentally.

Beware also of the mischief that may arise from the breaking of vessels containing large masses of liquid. When distillations are undertaken, or operations of any kind requiring much liquid are carried on, there should be no carpets or good furniture in the room.

The sort of experiments most proper for *the parlour-table* are those made with the blowpipe, and with tube-apparatus. Experimenting in miniature can be carried on to a great extent. There is scarcely an operation described in the preceding pages capable of producing results unattainable by an apparatus of blowpipes and test-tubes wrought with ease and safety over a tea-tray or a large earthenware dish. I would therefore recommend the young student to make his experiments on the smallest scale. It is what the oldest chemists are doing more and more every day. The cleverest philosopher is he who can effect a given object by the easiest means.

In the following list of apparatus and preparations, I notice what is required in a place where experiments in various branches of chemistry are carried on. It must necessarily be left to the taste and judgment of every reader to procure what appears to be most adapted to his particular wants.

It will be perceived, on an examination of the following pages, that the experiments are classed in groups, and that the apparatus required for each group is not the same as that required for another group. Thus, showy experiments on the properties of the gases require vessels much larger and more expensive than analytical experiments on the properties of salts, &c. On this account it is necessary for the student, before he begins to purchase apparatus, to consider what it is that he wants it for. I give this hint as the result of much dear-bought experience. When it was my fortune to be first astonished and delighted with the thunder and lightning of lecture-room experiments, I was led, in the enthusiasm of the moment, to purchase expensive instruments, for which I had not, and never shall have, the least use.

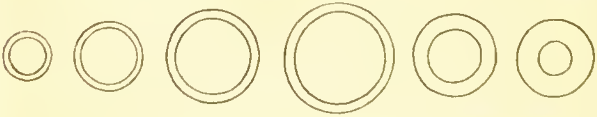
APPARATUS.—Bottles with glass stoppers; 6 capable of holding 4 ounces each, 6 of 2 oz., and 12 of 1 oz. These are to hold acids and re-agents. All your bottles should be short and broad, not long and narrow like apothecaries' phials. The latter will not stand safely.

Bottles, short and broad with wide mouths, to be closed by corks, and intended to contain chemical preparations in a dry state; 2 or 3 dozen.

Pill boxes and square card-boxes of all sizes; useful for containing preparations, specimens, ores, metals, &c.

Plenty of good corks of all sizes.

Glass tubes, of the diameter and thickness of glass shown by the figures. About a pound weight, of mixed sizes.



Apothecaries' scales, see page 3.

2 or 3 Florence flasks; see page 10.

Graduated measure for liquids; page 5.

Small Wedgewood's ware mortar; page 7.

Several Wedgewood's ware capsules; page 10.

Iron wire, page 14; copper wire, page 44.

A Woulfe's bottle, page 46.

Small glass retort, page 18.

Glass tubes of the forms exhibited at pages 11, 12, 20, 25, 26, 41, 46.

Several small glass funnels, page 27.

Some white blotting paper for filters, page 28.

2 or 3 Confectioners' glasses, page 10.

Blowpipe of brass or glass, page 41.

Piece of platinum foil, page 34.

Platinum wire, page 44.

Platinum capsule, page 13; spoon, page 34; and crucible, page 35.

Forceps, with platinum points, page 45.

Small spirit-lamp of tin or glass, page 37.

Large spirit-lamp, page 39; or oil-lamp, with circular wick, page 39.

Blowpipe-lamp, page 43. Any small oil-lamp will answer the same purposes in most cases.

A few watch glasses, page 13.

A nest of common Hessian crucibles, page 34.

Several Wedgewood's ware or porcelain crucibles of the smallest size, page 35.

Rats'-tail files; two small sizes for boring holes in corks.

A flat file for reducing the size of corks.

PREPARATIONS.—It is necessary, for experiments of research, where particular nicety is required, to be furnished with re-agents, in the very greatest possible degree of purity; but, for ordinary purposes—for the performance of such experiments as the student finds either necessary or agreeable—the different substances may be made use of in the degree of purity at which they are sold by respectable druggists, and at apothecaries' hall. In the experiments in this book, for which *pure* preparations are requisite, directions are given for purifying the preparations of *commerce*.

Solutions of salts must be prepared by dissolving the solid substances in distilled water; and liquids of all kinds must be preserved in glass bottles provided with glass stoppers; the use of corks is inadmissible. The bottles and stoppers must fit well to each other, otherwise something may get into or get out of the bottle, and in either case, spoil the re-agent. Thus, sulphuric acid may attract water from the atmosphere, or liquid ammonia may exhale ammoniacal gas.

You ought never to keep a large quantity of a test in solution, nor ever prepare a solution which is liable to spontaneous decomposition, until the moment when you are going to employ it. In general, your saline solutions should be nearly concentrated; that is to say, the water should contain nearly as much of the salt as it is capable of dissolving. If at any time you require a dilute solution, for accurate neutralisation or other purpose, you mix a little of the concentrated solution with distilled water in a separate glass.

Your test-solutions must always be transparent and free from deposit. In preparing them, you put the salt and water into a glass, and stir them until the water leaves no portion of the salt undissolved. You then pour the solution through a paper filter, and receive it in a bottle which must be previously placed below the neck of the funnel.

Many crystallised salts can be partially freed from their impurities, by re-crystallisation. You dissolve the crystals in distilled water, filter the solution through paper, and evaporate it in a Wedgewood's-ware basin, placed over a lamp or furnace, until its surface exhibits a species of film. You then set the solution aside on a cushion to crystallise, and when it is cold, you separate the crystals from the mother-liquor, which, if small in quantity, and not very valuable, is thrown away; but if of considerable bulk, is again evaporated, and set aside to produce a second crop of crystals.

Distilled Water.—This is a very important article in chemical operations. When a solution is to be prepared or diluted with water, it is *distilled water* which must be employed. The use of common water is capable of introducing a variety of impurities into the solutions, the presence of which might sometimes lead to terrible fallacies. You may purchase distilled water at the druggists, but it is cheaper to prepare it yourself, unless you happen to be in very inconvenient circumstances. In the small way, proceed as follows:—Pour a pint of water into a retort; distil over a wine-glassful into a receiver; use that quantity to wash the receiver; then distil over two-thirds of what remains in the retort, and preserve it for use. The retort can be heated over a lamp or charcoal fire; the receiver and the neck of the retort should be kept as cool as possible by the external application of cloth or paper wetted with cold water.

Alcohol.—That which is to be employed as a chemical test ought to be very pure and highly rectified. That which is intended for fuel for lamps may be impure and somewhat weaker, but it must not contain too great a quantity of water, otherwise it is less economical than strong alcohol, inasmuch as its combustion produces a very feeble degree of heat. You may burn pyro-acetic spirit for fuel, if you wish to save your money, and do not object to the smell of the spirit.

Turmeric Test Paper.—Boil a quarter of an ounce of pounded turmeric in half a tea-cupful of water for half an hour, and strain the decoction through muslin. Dip into this liquor a few pieces of thin yellow-wove post writing-paper, which will acquire a fine yellow colour. Dry the paper, cut it into slips two inches long and one-third of an inch wide, and preserve them in a box from light, atmospheric air, and acid vapour.

Litmus Test Paper.—This is prepared from a decoction of litmus, in the same manner as the turmeric test paper is prepared from a decoction of turmeric.

Mineral Acids.—The preparation of these re-agents is too difficult and dangerous to be undertaken by any but experienced chemists. I must counsel you, therefore, to buy them ready prepared, and always in the purest state you can meet with them. Ask for pure, or distilled acids. They are as follows :—

Sulphuric Acid.
Muriatic Acid.
Nitric Acid.

Remember that these acids decompose all vegetable and animal substances. If you touch them with your fingers, you burn yourself. If you drop them upon your clothes, you destroy the clothes. The bottles which contain them should be kept in a cool place, and nitric acid ought to be kept out of the light.

Caustic Potash.—Buy it in the solid state. Dissolve it in water; allow the impurities to subside; and decant the clear solution into the bottle in which it is to be preserved. Grease the stopper with tallow to prevent its sticking in the bottle. When you wish to remove a little of the solution of potash out of the bottle, make use of the dropping tube described at page 26; never pour the solution from the mouth of the bottle. This solution acts powerfully upon animal and vegetable substances. It cannot be filtered through paper.

Liquid Ammonia.—Buy it. The stopper of the bottle it is put into, must fit well, and the bottle must be kept in a cool place. It is employed to render acid and neutral solutions alcaline, when a change of state is necessary.

Carbonate of Potash.—The *sal tartari* of the apothecaries is carbonate of potash in a state of impurity. Buy crystallised bicarbonate of potash, ignite it in a platinum crucible over a large spirit-lamp; dissolve the residue in distilled water, and filter the solution.

Carbonate of Soda.—Buy purified carbonate of soda in crystals. Purify it by re-crystallisation. Dissolve it in distilled water. It is a test for many bases. The powdered crystals are used in experiments with the blowpipe.

Carbonate of Ammonia.—Buy it in the solid state, dissolve it in distilled water, and filter the solution. The bottle must have a stopper that fits well, and should be kept in a cool place.

Gases, and Solutions of Gases.—When you begin to make analytical experiments, you will soon find the want of two or three gases, or their solutions in water; these are sulphuretted hydrogen gas, chlorine gas, hydrogen gas, and carbonic acid gas. Directions for preparing these gases will be given in a subsequent part of this work, and instructions for preparing solutions of such as are soluble have been already given, (page 53.)

Oxalic acid, crystallised, half oz.
Tartaric acid, crystallised, one oz.
Citric acid, crystallised, one oz.
Boracic acid, crystallised, quarter oz.

SALINE SOLUTIONS REQUIRED FOR TESTS.—Buy the fifteen following salts in the state of purified crystals. Dissolve the crystals in distilled water, filter the solutions, and recrystallise the salts (p. 21). Dissolve the purified crystals in water, filter the solutions, and preserve them for tests. The same substance should be kept in the dry state for other experiments, and for the preparation of solutions when required.

1. *Nitrate of Silver.*—The solution must be preserved in a dark place, because light decomposes it. This solution stains your fingers black, and forms indelible black stains on linen. It is very poisonous,—one-fourth oz.
2. *Chloride of Barium* (Muriate of barytes), one-half oz.
3. *Nitrate of Barytes*, one-fourth oz.
4. *Acetate of Barytes*, one-fourth oz.
5. *Oxalic Acid*, one-half oz.
6. *Superoxalate of Potash*, one-half oz.
7. *Oxalate of Ammonia*, one-half oz.
8. *Sulphate of Potash*, one oz.
9. *Sulphate of Soda*, one oz.
10. *Phosphate of Soda*, one-fourth oz.
11. *Yellow Prussiate of Potash*, one oz.

12. *Chromate of Potash*, one-fourth oz.
13. *Nitrate of Potash*, one oz.
14. *Iodide of Potassium*, one drachm.
15. *Sulphate of Copper*, one oz.
16. *Red Prussiate of Potash.* Must be prepared.

Other useful Salts :—

Acetate of Lead, one oz.
Borax, one oz.
Carbonate of Barytes, half oz.
Carbonate of Magnesia, hf. oz.
Sulphate of Magnesia, one oz.
Native fluor spar.
Sal Ammoniac, one oz.
Alum, one oz.
Sulphate of Iron, one oz.
Sulphate of Soda, one oz.
Cream of Tartar, one oz.
Common Soda, two oz.

Tests for peculiar experiments :—Lime Water ; Indigo dissolved in Sulphuric acid ; Sulphate of Strontian ; Sulphate of Lime ; Sulphate of Silver ; Nitrate of Cobalt ; Protochloride of Tin ; Chloride of Platinum ; Chloride of Gold ; Perchloride of Iron ; Tincture of Galls.

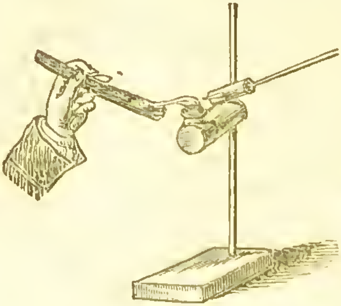
Metals.—Iron filings, thick polished wire, and polished plates—Copper clippings—get some slips of thin copperplate from a coppersmith, clean them bright with pumice stone and water, and clip them into very small pieces. Cut some of the same copper slips, into pieces of one-third of an inch wide, and three inches long, and finely polish them, these are to be used in precipitating silver, &c. from solution. Zinc, in lumps, may be bought of brass founders for 9d a pound. If you cast plates for a galvanic pile, you will want two pounds. Zinc can also be purchased in thin plates, rolled zinc being now an article of commerce ; granulated zinc, a few ounces, for making hydrogen gas. Gold leaf, a small quantity from a gold beater. Granulated tin, (called by dyers *dropt* tin), one oz. 1d. Tin foil, a square foot, 2d. Mercury, one oz. 4d. To be kept corked in a phial. Bismuth, one oz. 6d. Antimony, one oz. 6d. Cobalt, 1 drachm.

Miscellaneous Articles.—Starch, one-fourth oz.—Nut-Galls, one-half oz.—Olive Oil, one oz.—Oil of Turpentine, two oz.—Phosphorus, one-fourth oz.—preserved in water, corked in a phial, and placed in a dark situation. Roll sulphur, flowers of sulphur, chalk, pipe clay, red lead, of each a penny worth. Pieces of white marble.—Sulphuric Ether, one-half oz. To be kept in a well closed phial, in a cool place.—Turmeric, one-half oz.—Litmus, one-half oz. —Oxide of Manganese, a pound 6d or 8d.—This is to furnish oxygen.—Sulphuret of Antimony, one oz.—Best Indigo, one-fourth oz.—Cochineal, one half oz.—Logwood, one oz.—Brazil Wood, one oz.—Gum benzoin, one-half oz.

Cleansing.—When an experiment is ended, the vessels employed in it must be thoroughly cleansed and put away. Wash glasses in a tub with water. Do not rub them with sand to get them clean. Use tow and copper wires to cleanse the inside of glass tubes. A stick and towel can be used in cleansing the inside of large glasses. An old silk handkerchief is very good to clean small glasses with. Oil flasks can be cleaned out by a little oil of vitriol. Resins and turpentine can be cleaned out by alcaline solutions. The sooner you cleanse vessels after they are done with, the easier the dirt comes off. It is a very troublesome and expensive practice to allow dirty glasses to accumulate.

In concluding my instructions relating to manipulation, I once more urge upon the student the necessity of his learning to use the blowpipe. The advantages of this little instrument, both in analytical inquiries, and in the preparation of small glass apparatus, are so numerous and so well understood, that it is coming into general use; and in a short time, that man will be considered a poor chemist who does not know

How to hold the Blowpipe.



CHARACTERS OF CHEMICAL BODIES.

ACCORDING to the present views of chemists, there are fifty-four elementary substances; that is to say, fifty-four substances which individually differ in properties from every other substance, and which, by their various combinations, produce the diversified compounds that constitute the material world. The names of these fifty-four simple substances are as follow :—

Oxygen
Sulphur
Nitrogen
Chlorine
Bromine
Iodine
Fluorine
Phosphorus
Selenium
Arsenic
Chromium
Vanadium
Molybdenum
Tungsten
Boron
Carbon
Antimony
Tellurium
Tantalum
Titanium
Silicium
Hydrogen
Osmium
Gold
Iridium
Rhodium
Platinum
Palladium
Mercury
Silver
Copper
Uranium
Bismuth
Tin
Lead
Cerium
Cobalt
Nickel
Iron
Cadmium
Zinc
Manganese
Thorium
Zirconium
Aluminum
Yttrium
Glucinum
Magnesium
[Ammonium]
Calcium
Strontium
Barium
Lithium
Sodium
Potassium

[Ammonium is a compound of nitrogen and hydrogen; but the substances in which it is found, and from which it cannot be separated without suffering decomposition, have properties similar to those of the substances formed by the simple body termed potassium. Hence this suppositious compound acts the part of an elementary body.]

The arrangement of the matter in the following pages is very simple. Every element has a short notice devoted to it; and these notices are arranged in the order of the names in the above list. And in respect to the compounds produced by the combination of the elements, each is noticed in the article which treats of the particular element the name of which is *lowest* in the above list. Thus, sulphurous acid, which is composed of sulphur and oxygen, is noticed in the article on sulphur; sulphuret of potassium, which contains sulphur and potassium, is noticed in the article on potassium; and sulphate of barytes, which contains oxygen, sulphur, and barium, is described under the head of barium.

OXYGEN.

Oxygen forms a colourless and inodorous gas, which is nearly insoluble in water, has no action on lime-water, and does not change the colour of tincture of litmus. It is distinguished from other gases by supporting combustion with great vigour. If a glowing match is held in a glass containing oxygen gas, the match instantly inflames, and burns with much greater brilliancy than in common air. Various gases which cannot alone support combustion, acquire that property when mixed with oxygen. This is the reason that combustible bodies burn in common air, which contains one part of oxygen gas mingled with four parts of nitrogen gas. Animals live longer in a given bulk of oxygen gas than in the same bulk of common air.

Oxygen gas is heavier than common air, in the proportion of 4·0 to 3·6. The number 4·0 is taken in this work to represent the specific gravity of oxygen gas. A cubic inch of oxygen gas, taken when the barometer stands at 30 inches, and the thermometer at 60° F., weighs 0·34, or nearly one-third, of a grain.

Compounds of Oxygen. A variety of compounds are formed by the combination of oxygen with other elements. Thus, water consists of oxygen and hydrogen; air, of oxygen and nitrogen; sulphurous acid, of oxygen and sulphur; aquafortis, of oxygen, nitrogen, and hydrogen; potash, of oxygen, hydrogen, and potassium; black oxide of copper, of oxygen and copper; lime, of oxygen and calcium; and so forth. None of the compounds containing oxygen exhibit acid properties in the absence of hydrogen.

Instructions for the Preparation of Oxygen Gas. 1st method. Put into a glass retort a mixture composed of bisulphate of potash, 10 parts, and powdered black oxide of manganese, one part. Connect the retort with a tube for conducting gas (page 47), and apply heat to the retort by means of a lamp. The mixture speedily disengages a considerable quantity of oxygen gas, which is to be collected over water, in the manner described in the section on the "Management of Gases," page 48.—2d method. Pour oil of vitriol into a tubulated retort, through a funnel, till the retort is one-third filled. Take an equal weight of black oxide of manganese, and pour it into the retort through a warm dry funnel, taking care to shake the retort from time to time, so as to incorporate the two ingredients thoroughly. Apply heat by means of a lamp or charcoal fire, and let it be well sustained, so that the water of the pneumatic trough may not run back into the retort and break it. The dry sulphate of manganese is afterwards removed from the retort by being soaked and softened with water.—3d method. When a large quantity of oxygen gas is required, it is usual to ignite dry peroxide of manganese in an iron retort, or quicksilver bottle, or a gun barrel, placed in a furnace or open fire.—4th method. Put a small quantity of red oxide of mercury into a very small retort, or into a glass tube, and apply heat. The oxide is decomposed, metallic mercury volatilises and condenses in the receiver, if one is placed to receive it, and oxygen gas, in a state of greater purity than that afforded by the foregoing methods, is disengaged from the extremity of the apparatus.—5th method. Put the salt called chlorate of potash into a small retort, and expose it to heat: the retort must only be one-third full, and is best when formed of green glass. The salt soon melts, and gives off two-fifths of its weight of the purest oxygen gas which it is possible to procure.

SULPHUR.

At the ordinary temperature of the atmosphere, sulphur is a solid substance, exhibiting a shelly fracture and a yellow colour. When it is obtained in crystals by proper treatment of a solution of sulphur, or when found in the vicinity of burning mountains, it is transparent; but when it has been submitted to fusion, it is opaque. When obtained in the state of powder, and particularly when produced in an aqueous solution, its colour is nearly white. It is brittle. It burns in the air with a blue flame, and diffuses a peculiar odour, which is due to the presence of sulphurous acid gas. It fuses at a temperature rather higher than that of boiling water, and forms a perfect fluid, while at a still higher temperature it becomes thick and gluey, and acquires a brown colour. If the thick fluid is put into water, it produces a brown tenacious mass, which ultimately becomes solid, brittle, and yellow. If the melted sulphur is raised to a very high degree of heat in closed vessels, it boils, and is converted into a deep orange-coloured gas, which appears to the eye like nitrous acid gas. If this gas is inflamed in the air, it burns, like sulphur, with a blue flame and a smell of sulphurous acid. It is in consequence of the production of this peculiar odour by combustion, that the presence of sulphur is very easy of detection.

When sulphur is boiled with nitric acid in a flask, it dissolves, and produces oil of vitriol. Nitric acid of ordinary strength effects this oxidation with much difficulty; but fuming nitric acid is capable of dissolving sulphur with far greater facility. Muriatic acid does not dissolve sulphur. Aqua regia, or a mixture of nitric acid and muriatic acid, converts sulphur into oil of vitriol more readily than either of the acids alone. Chlorine gas led over powdered sulphur, produces chloride of sulphur. A solution of pure potash dissolves sulphur at a boiling heat, and the resulting solution contains sulphuret of potassium and the saline compound termed hyposulphite of potash.

Sulphur combines with Oxygen.—Only two compounds are known at present. Their composition is as follows:—

Sulphur.	*Oxygen.*	*Resulting Compounds.*
4	4	Sulphurous acid.
8	12	Anhydrous sulphuric acid.

Other Combinations of Sulphur.—Sulphur combines with hydrogen to form sulphuretted hydrogen; with oxygen and hydrogen jointly, to form oil of vitriol or hydrate of sulphuric acid; with oxygen and metals it forms salts, which are termed sulphates; with metals, without oxygen, it forms metallic sulphurets. It forms many other compounds. Annexed is a Table exhibiting the proportions by weight of the elements which enter into the composition of a variety of sulphates.

Sulphur.	Oxyg.	Radical.		Names and Weights of the Sulphates.	
4	8	0·25	Hydrogen	12.25	Oil of vitriol
4	8	26·0	Lead	38·0	Sulphate of protoxide of lead
4	8	17·5	Barium	29·5	Sulphate of barytes
4	8	5·0	Calcium	17·0	Sulphate of lime
4	8	10 0	Potassium	22·0	Sulphate of potash
4	8	6·0	Sodium	18·0	Sulphate of Soda
4	8	8·0	Copper	20·0	Bisulphate of deutoxide of copper
4	8	8·0	Zinc	20·0	Sulphate of oxide of zinc
8	12	…………		20·0	Anhydrous sulphuric acid

This table shows that oil of vitriol is a true sulphate, differing from the metallic sulphates in no other respect than in substituting a definite quantity of hydrogen for an equivalent proportion of metal.

Sulphurous Acid Gas.—This compound gas is colourless, incombustible, incapable of supporting combustion, and possessed of a peculiar suffocating odour; it reddens wet litmus paper, and bleaches many vegetable colours. One volume of sulphurous acid gas contains one volume of oxygen gas. The specific gravity of sulphurous acid gas is 8, that of oxygen being 4. Hence it contains equal weights of oxygen and sulphur. A cubic inch of it weighs 0·68, or two-thirds, of a grain. By pressure or great cold, it is made to assume a liquid form.

Preparation of Sulphurous Acid Gas.—Take equal weights of metallic mercury and concentrated sulphuric acid; pour them into a retort or flask, and apply the heat of a lamp. This gas is absorbable by water, and cannot be collected in jars placed over the water trough. It must therefore be collected over mercury, or else by the method of displacement described at page 51. Let each bottle of gas be corked and secured with soft cement (p. 57) as soon as it is full.

Liquid Sulphurous Acid.—To prepare a solution of sulphurous acid gas in water, you pass the gas into water as long as the water continues to absorb it. See "Solution of Gases," p. 53. To prepare *Sulphites*, you pass the gas in a similar manner into solutions of alcalies, &c.

NITROGEN.

Nitrogen forms a colourless and inodorous gas, which is more difficult to be recognised than most other gases. It is incapable of supporting combustion, on which account the combustion of burning bodies is put an end to when they are plunged into it. It is incapable of being inflamed, which character distinguishes it from hydrogen gas. It produces no precipitate when shaken in a bottle with lime water. It cannot support animal life. The specific gravity of nitrogen gas is 3·5, that of oxygen gas being 4. A cubic inch of it weighs 0·2975 of a grain.

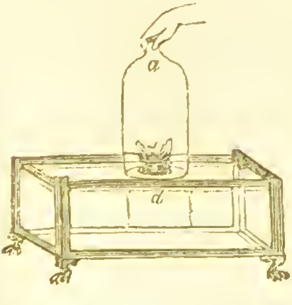
Nitrogen combines with Oxygen.—The following table shows the constitution of the various compounds formed by the combination of oxygen and nitrogen.

	By Volume.		By Weight.		Resulting Volume.	Specific Gravity.
	Oxyg.	Nitrog.	Oxyg.	Nitrog.		
Nitrogen Gas	—	1	—	3·5	1	3·5
Nitrous Gas	1	1	4	3·5	2	3·75
Nitrous Oxide Gas	1	2	4	7·0	2	5·5
Nitrous Acid	2	1	8	3·5	?	?
Atmospheric Air	1	4	4	14·0	5	3·6

Other compounds of Nitrogen.—With oxygen and hydrogen it forms aquafortis, or hydrate of nitric acid (pure or dry nitric acid is a chimerical compound); with hydrogen it forms ammonia; with oxygen and metals it forms the salts which are called nitrates; with carbon it forms cyanogen; with carbon and hydrogen it forms prussic acid; with a certain quantity of hydrogen it forms a prime constituent of a series of salts, in which the compound of nitrogen and hydrogen seems to act the part of a metal. The following table exhibits the composition of various nitrates. It will be perceived that aquafortis or hydrate of nitric acid is a true nitrate, differing no otherwise from the nitrates of metals than in containing 0·25 of hydrogen, in place of an equivalent proportion of a metal.

Nitrog.	Oxyg.	Radical.	Names and Weights of the Nitrates.
3·5	12·	0·25 Hydrogen	15·75 Aquafortis
3·5	12·	27·5 Silver	43·0 Nitrate of oxide of silver
3·5	12·	26·0 Lead	41·5 Nitrate of protoxide of lead
3·5	12·	17·5 Barium	33·0 Nitrate of barytes
3·5	12·	10·0 Potassium	25·5 Nitrate of potash
7·0	20·		27·0 Imaginary dry nitric acid

Preparation of Nitrogen Gas.—5 Volumes (measures) of atmospheric air contain 4 volumes of nitrogen gas, and 1 volume of oxygen gas. If the latter is absorbed by a combustible body, the former remains in an uncompounded state. (*a*) Put a morsel of phosphorus into a little porcelain capsule, place the capsule upon a large cork swimming on the water of the pneumatic trough (*d*); set fire to the phosphorus, and cover the capsule with a bell glass gas-receiver (*a*), open at bottom and closed at top. The oxygen of the air combines with the phosphorus, and produces white vapours of phosphoric acid, which dissolve in the water, and leave the nitrogen gas in a state of tolerable purity. 10 Cubic inches of air require about 1 grain of phosphorus to render this experiment successful.—(*b*) Introduce a lighted taper under a glass jar, standing over water, and filled with common air. The light will shortly be extinguished, a cloudiness will be perceived, which, however, will soon subside, and the water



in the basin will rise in the jar.—*Rationale.* The atmospheric air is decomposed; the oxygen is absorbed by the burning taper, and the nitrogen remains. The cloudiness proceeds from the unconsumed smoke of the taper. The water rises in the jar, because the included volume of air, is, by the absorption of its oxygen, diminished. The nitrogen gas produced by this process is less pure than that afforded by process (*a*).

Atmospheric Air, is the term applied to that immense mass of permanently elastic fluid, which surrounds the globe we inhabit. This substance was for a long time supposed to be simple, but recently it has been proved, by experiment, to be a compound of oxygen and nitrogen. 5 Parts of common air, contain 1 part by measure of the former body, and 4 of the latter. The proportions of these two gases, in atmospheric air, are uniform and constant. They have been found to be the same in all parts of the world, and in all seasons of the year. The density of air is 825th that of water. A cubic inch (barometer 30 inches, thermometer 60°) weighs 0·306 grain. Its physical properties, such as its transparency and elasticity, are so obvious, as not to require description. Air which has been breathed, is found to have lost its oxygen, and is then no longer fit to support life. This element is retained in the lungs, where it is absorbed by the blood, from which it expels *carbonic acid gas*, and which it renders capable of supporting life. The red colour of the blood is owing to the oxygen it acquires in passing through the lungs.

Formation of Atmospheric Air.—If one cubic inch of oxygen gas is mixed with four cubic inches of nitrogen gas, the resulting mixture is one which agrees in all its properties with the air of the atmosphere.

Nitrous Oxide Gas.—It supports combustion, but (though it may be respired) is not capable of supporting life. It has a sweet taste, and a faint, but agreeable odour. Water which has been boiled, absorbs only about one-half of its bulk of it, and acquires thereby no other property than that of sweetness. The most extraordinary property of this gas, is its action on the human body, when respired. The sensations that are produced vary greatly in persons of different constitutions; but in general they are highly pleasurable, and resemble those attendant on the pleasant period of intoxication. It has been called *intoxicating gas*, *laughing gas*, and *gas of Paradise*. This characteristic of nitrous oxide gas was discovered by Sir Humphry Davy.

To procure Nitrous Oxide, or Intoxicating Gas.—Put a quantity of nitrate of ammonia into a glass retort, and apply the heat of a lamp, which must be gentle, and well regulated. The salt will in a short time liquify, and must then be kept gently simmering, avoiding violent ebullition, otherwise the gas will be impure. The gas may be collected over water, and must be allowed to stand a few hours before it be used; during which time it will deposit a kind of white vapour, and will become perfectly transparent. Four ounces of nitrate of ammonia produce a cubic foot of nitrous oxide gas.—Do not dip the neck of the retort into the trough till the gas passes out rapidly, which you ascertain by holding the mouth of the retort in a small capsule containing water.

Nitric Oxide, or *nitrous gas*.—It is colourless, but when suffered to mix with air, or with oxygen gas, it produces brilliant red fumes, being by its union with oxygen converted into nitrous acid gas. Nitrous gas does not redden litmus. It is not combustible; it is fatal to animal life, and extinguishes flame. There are, however, a few bodies that can be burnt in it. Water absorbs about 1-20th of its bulk of this gas.

Preparation of Nitrous Gas.—Put 100 grains of shreds of copper into a retort, and add 300 grains of nitric acid, diluted with twice its bulk of water. Collect the gas which is then disengaged over water. When the evolution of gas ceases, the application of a gentle heat will cause the production of another portion of gas. A blue liquid will remain in the retort, which liquid is a solution of nitrate of copper. Preserve it for other experiments.

Nitrous Acid.—The red fumes produced by the mixture of nitrous gas and oxygen gas, consist of nitrous acid gas. It is very seldom prepared in a pure state. The salts termed *nitrites* are constituted like the nitrates, excepting that they contain one-third less oxygen.

CHLORINE.

Chlorine forms a yellowish green gas, which by great pressure can be reduced to a dark yellow oily liquid. Chlorine gas has a suffocating odour; is heavier than oxygen gas in the proportion of 9 to 4; is capable of supporting the combustion of a variety of substances. With a small quantity of water, it forms yellow crystals; with a large quantity, it produces a solution commonly called *liquid chlorine;* this solution has a choking odour like the gas, and possesses the property of bleaching all vegetable colours, which property is also possessed by the gas when mixed with vapour of water, but not otherwise. The solution does not absorb a very large quantity of chlorine, nor does it remain long without undergoing decomposition. Warm water absorbs a very slight quantity of chlorine gas.

Chlorine combines with oxygen. The following table shows the constitution of the two compounds of chlorine and oxygen, both of which are gaseous:—

	By Volume.		By Weight.		Resulting Volume.	Specific Gravity.
	Chlorine.	Oxyg.	Chlorine.	Oxyg.		
Protoxide of Chlorine	2	1	18	4	2·5	8·8
Deutoxide of Chlorine	1	2	9	8	2	8·5

Other Compounds of Chlorine.—With oxygen and hydrogen it forms chloric acid; with oxygen and metals it forms the salts termed chlorates; with hydrogen it forms muriatic acid; with the metals it forms the compounds or salts termed chlorides, an example of which is afforded by common salt, a compound of chlorine and sodium; with sulphur, nitrogen, carbon and other elements, it produces a great variety of chlorides and more complex compounds. The following table exhibits the constitution of some of the most important compounds of chlorine:—

Chlorine.	Oxyg.	Other Elements.	Weights and names of the compounds.
18	4		22· Protoxide of Chlorine
9	8		17· Deutoxide of Chlorine
9		0·25 Hydrogen	9·25 Muriatic Acid
9		6· Sodium	15· Chloride of Sodium
9		27·5 Silver	36·5 Chloride of Silver
9		1·0 Hydrogen 3·5 Nitrogen	13·5 Sal Ammoniac (chloride of Ammonium)
9		10· Potassium	19· Chloride of Potassium
9	12	10· Potassium	31· Chlorate of Potash
9	16	10· Potassium	35· Perchlorate of Potash
9		4· Sulphur	13· Chloride of Sulphur

Muriatic acid is a true chloride, differing from the chlorides of metals only in having 0·25 of hydrogen instead of an equivalent proportion of a metal. Muriate of ammonia is also a true chloride, containing hydrogen and nitrogen jointly in place of a metal. The German chemists call it chloride of ammonium, and suppose the 1 of hydrogen and 3·5 of nitrogen to form a metal which they call ammonium. This supposed metal has never, however, been obtained in a separate state.

Preparation of Chlorine Gas.—Put into a glass flask or gas-bottle, two or three ounces of a mixture of equal bulks of oil of vitriol and muriatic acid; then add an ounce of finely-pulverised peroxide of manganese, previously warmed to make it pour easily through a dry funnel. Shake the flask as the powder is poured in, to make it mix well with the liquid. Fit a gas-tube to the neck of the flask, and expose the mixture to a gentle and regular heat, applied by means of a sand-bath or lamp. The gas is disengaged pretty rapidly.

Chlorine gas, being absorbable by *cold* water, must be received in bottles filled with, and inverted in, *warm* water, of a temperature made by mixing two parts of cold with one of boiling water. The bottles must be provided with accurately-ground stoppers, which must be introduced under water while the bottles remain full of gas: no water must be left in the bottle with the gas.—Chlorine gas may be collected in dry vessels by the method described at page 51.

In experiments with this gas, great care should be taken that it do not escape in any considerable quantity into the apartment, as its action on the lungs is extremely injurious.

Liquid Chlorine.—I mean by this term, a solution of chlorine gas in water. It is prepared by the process described under "Solution of Gases," page 53.

The Oxides of Chlorine.—It is dangerous to make experiments on these compounds.

BROMINE.

At the ordinary temperature of the atmosphere, bromine forms a dark reddish-brown liquid, which is heavier than water. It possesses an odour which peculiarly affects the temples, and is thus distinguished from chlorine, which acts on the throat, and from iodine, which affects the nose. It boils at a low temperature, and produces a reddish-brown gas. With a small quantity of water, it forms crystals; with a large quantity, it gives a hyacinth-red solution. It bleaches vegetable colours, and forms with other elements, a series of compounds which much resemble those formed by chlorine. Its compounds are termed *bromides.* It is very scarce and expensive.

IODINE.

Iodine, at common temperatures, forms black crystals, which resemble plumbago. It is heavier than water. Its odour is something like that of chlorine, but weaker, and distinguished by the difference noted under Bromine. It fuses at a temperature a little above that of boiling water; and, when strongly heated, volatilises in the form of a splendid violet-coloured gas. Its taste is sharp and acrid; it is poisonous; it bleaches vegetable colours slightly; it colours the skin yellow, and makes paper brown, but the colours are fugacious. It is slightly soluble in water, and readily soluble in alcohol. It forms a blue compound with starch.

The compounds which iodine forms with other elements, bear a great resemblance to the compounds produced by chlorine. They are called *iodides.*

FLUORINE.

Fluorine has never been completely separated from other substances. All its compounds can be readily decomposed; but when the fluorine is liberated from one element, it instantly seizes upon another. It is like the Alchymists' Universal Solvent, which was to be able to dissolve *everything*, and which, therefore, must have dissolved the very vessels which they intended to put it in—when they had discovered it!

Compounds of Fluorine.—With hydrogen it produces hydrofluoric acid; with metals it produces fluorides. Hydrofluoric acid is a true fluoride, in which 0·25 of hydrogen occupies the place of an equivalent proportion of a metal. The constitution of hydrofluoric acid resembles the constitution of muriatic acid.

PHOSPHORUS.

Phosphorus, at the ordinary temperature of the air, is solid, of a yellow colour, transparent, flexible like wax, and heavier than water. It melts upon being gently heated, or when warm water is poured upon it. If excluded from air and exposed to a higher temperature, it volatilises, and can be distilled. Its gas is colourless.

In the presence of air, phosphorus readily inflames; a gentle friction is sufficient to cause its combustion. In hot weather, it often inflames spontaneously, especially if exposed to the air upon rough bodies, such as coarse blotting-paper. It burns with a strong flame, and produces a thick white smoke. It gives light in darkness; and this light is most powerfully produced when a stick of phosphorus is placed in nitric acid, in such a manner that a portion projects above the liquid. It diffuses white vapours in the air. Its odour is peculiar, but somewhat resembles that of garlic. It is poisonous.

Compounds of Phosphorus.—With oxygen it forms anhydrous phosphorus and phosphoric acids; with hydrogen it forms two species of very inflammable gas, both of which have the same composition; with oxygen and hydrogen jointly, it forms phosphoric acid and phosphorous acid; with chlorine it forms two compounds; with metals it forms phosphurets; with metals and oxygen jointly it forms phosphates, phosphites, and hypophosphites. It dissolves sparingly in alcohol, oils, and ether.

Nitric acid and aqua regia easily dissolve phosphorus, and produce phosphoric acid. Muriatic acid does not dissolve phosphorus. If chlorine gas is passed over heated phosphorus, it produces a solid or a liquid chloride of phosphorus, according as more or less chlorine is employed. In a solution of pure potash, phosphorus dissolves under disengagement of spontaneously inflammable phosphuretted hydrogen gas. Phosphuret of potassium dissolves in water, under disengagement of the same gas. Other phosphurets require nitric acid for solution.

Phosphorus is prepared by distilling a mixture of burned bones and charcoal. The operation is too troublesome and dangerous to be undertaken by unpractised students. Phosphorus can be purchased of apothecaries for experiments.

It is procured in sticks like those of caustic potash. These must be preserved in water, corked in a bottle, and placed in a dark and cool situation. Phosphorus requires to be handled with much caution.

SELENIUM.

SELENIUM is solid, brittle, and of shelly fracture. It has a metallic splendour; its colour is black or dark grey; it is opaque. Thin slips have a red colour, and are transparent; the fine powder is dark red. It readily fuses; heated and protected from air, it boils and produces a dark yellow gas. It burns in the air with a blue flame, and diffuses a powerful odour of decayed horse-radish. It dissolves in nitric acid and aqua regia with heat, and produces selenious acid.

Compounds of Selenium.—They very much resemble those of sulphur. With oxygen it forms selenious acid; with hydrogen it forms seleniuretted hydrogen; with oxygen and hydrogen jointly, it forms selenic acid; with oxygen and metals jointly, it forms seleniates, which are very similar to sulphates; with metals it forms seleniurets. The composition of the compounds of selenium are equivalent to those of sulphur, excepting that every 4 parts by weight of the latter are replaced by 10 parts by weight of the former. Selenium is extremely rare.

ARSENIC.

METALLIC arsenic forms rinds and crystalline masses of a steel-grey colour, and a metallic splendour, but which are subject to lose their splendour and become black on exposure to the air. It is brittle, and easy to powder. When heated, it readily volatilises without undergoing fusion. The vapour possesses a peculiar odour, resembling that of garlic. When heated in the air, it produces a white smoke, which is arsenious acid. When more powerfully heated, or when heated in oxygen gas, it burns with a pale blue flame.

It dissolves in hot nitric acid, producing arsenious acid. It dissolves in aqua regia, producing arsenic acid. It is insoluble in muriatic acid. The arseniuret of tin or of zinc dissolves in muriatic acid, under disengagement of arseniuretted hydrogen gas. Arsenic and all its compounds are poisonous. Arseniuretted hydrogen gas is peculiarly dangerous. Its smell is deadly.

Compounds of Arsenic.—With oxygen it forms arsenious and arsenic acid; with sulphur it forms sulphuret of arsenic; with metals it forms arseniurets; with oxygen and metals jointly it forms arsenites and arseniates; with hydrogen it forms arseniuretted hydrogen.

Preparation of Metallic Arsenic.—Pulverise some charcoal, recently ignited, to free it from water; mix the powder with a little white arsenic; put the mixture into a glass test-tube, and heat it over a spirit-lamp. The white arsenic will be decomposed, and metallic arsenic will sublime and settle upon the sides of the tube, producing a species of metallic mirror.

Arsenious Acid. White Arsenic.—A heavy, white powder, which sublimation converts into a white, glassy mass. Very volatile, easily reducible by ignition with charcoal, sparingly soluble in water. A violent poison. Arsenites of the alcalies are formed by dissolving white arsenic in hot solutions of the caustic alcalies.

Arsenic Acid.—Solid, fusible, colourless, glassy.

Sulphurets of Arsenic.—(*a*) *Red Sulphuret,* or *Realgar*; a yellowish-red, transparent, glassy mass, with glancing, shelly fracture. Very fusible and volatile. Used as a colour, and in the preparation of *white fire* for signals.—(*b*) *Yellow Sulphuret of Arsenic,* or *Orpiment.* Prepared by melting sulphur with white arsenic, but then contains the latter in excess. Prepared also by precipitating arsenic from an acidulated solution, by means of a current of sulphuretted hydrogen gas. A beautiful lemon-yellow powder, easily fusible, and volatile. Used as a yellow pigment.—Both of these sulphurets burn in the air with a blue flame.

CHROMIUM.

Chromium has a greyish-white colour, is brittle, and very difficult of fusion. It is not acted on by air, nitric acid, or aqua regia; but is dissolved by hydrofluoric acid.

Compounds of Chromium. With oxygen it forms a fine green oxide; with oxygen and hydrogen it forms a solid red crystalline acid; with oxygen and metals it forms the beautiful salts called chromates and bichromates; with chlorine, fluorine, &c., it forms various compounds.

Green Oxide of Chromium.—Prepared by igniting a mixture of chromate of potash, carbonate of soda, and sal ammoniac. The oxide is separated by solution and filtration. An insoluble, infusible, green powder, nearly insoluble in acids after ignition, and very difficult of reduction.

Chloride of Chromium.—Prepared by distilling a mixture of chromate of potash, chloride of sodium, and oil of vitriol. A blood-red, very volatile and fuming liquid, which water decomposes into muriatic acid and chromic acid.

VANADIUM.

VANADIUM is white, and much resembles silver, but is still more like molybdenum. It is brittle. It conducts electricity. It dissolves easily in nitric acid and in aqua regia, producing blue solutions. It is not attacked by muriatic acid, sulphuric acid, nor fluoric acid, nor yet by solutions of alcalies. It combines with sulphur and oxygen.

MOLYBDENUM.

MOLYBDENUM, in the melted state, is silver-white and slightly malleable. It is very difficult of fusion. It commonly appears in the form of grey metallic powder. When heated in the air, it produces various oxides, according to the temperature it is exposed to. Muriatic acid does not dissolve molybdenum. Nitric acid easily dissolves it, producing molybdic acid; or, if the nitric acid is in too small a quantity, producing nitrate of molybdenum.

TUNGSTEN.

TUNGSTEN, in the fused state, is steel-grey, lustrous, very hard, brittle, and extremely heavy. It is exceedingly difficult of fusion. It is commonly obtained in the form of iron-grey powder. When heated in the air, it produces tungstic acid.

BORON.

Boron forms a dark olive-coloured powder. When heated in close vessels it shrivels up, but does not volatilise. When heated in the air, it burns in a lively manner, and acquires a coating of dry boracic acid. Aqua regia and nitric acid convert it into boracic acid. Chlorine changes it into gaseous chloride of boron. When mixed and heated with nitrate of potash it explodes. The most important compounds of boron are boracic acid and borax.

CARBON.

The different kinds of carbon, or charcoal, have a very different appearance, and also extremely different properties. The purest variety of carbon is the diamond. This is crystalline and colourless, possessed of remarkable brilliancy, and a hardness exceeding that of all other bodies. Occasionally, it is found coloured. The other varieties of carbon, which often contain very small quantities of foreign substances, are all black, opaque, and in general dull. Sometimes they are pulverulent, sometimes solid and porous, sometimes glossy and crystalline, as in the instance of plumbago. In the presence of air, most sorts of carbon burn into carbonic acid gas or carbonic oxide gas, and so fly away, leaving behind only a small residue of ashes. Diamond and plumbago require, however, an exceedingly high temperature for their combustion. All the varieties of carbon are insoluble in water, infusible by heat, and incapable of being volatilised. When charcoal is boiled in nitric acid, it disengages carbonic acid gas; when it is mixed with nitre and heated, it explodes.

Carbon has a strong tendency to combine with oxygen, and is on that account often employed to separate oxygen from other substances. It is employed with advantage to purify various substances. Carbon combines with oxygen, and produces a gas called carbonic acid; and, when combined with hydrogen gas, forms carburetted hydrogen gas —the same that is now used to light up shops. Animal and vegetable oils, are composed almost entirely of carbon and hydrogen; the difference in their properties resulting chiefly from the variation in the proportions of these two bodies. The same may be observed of gum, sugar, and starch. All these bodies, however, contain oxygen.

If you expose sugar, starch, or wood to a strong heat (over a spirit lamp), in a glass tube, these substances will be decomposed, and you will obtain charcoal—the oxygen and hydrogen of the compounds escaping in the state of water.

Compounds of Carbon.—With oxygen it produces two gaseous compounds, the constitution of which is as follows:—

	By Volume.		By Weight.		Resulting Volume.	Specific Gravity.
	Carbon.	Oxyg.	Carbon.	Oxyg.		
Carbonic Oxide,	1	1	3	4	2	3·5
Carbonic Acid,	1	2	3	8	2	5·5

Composition of *one part* in weight:—

	Carbonic Oxide.	Carbonic Acid.
Carbon,..........	0·428571	0·272727
Oxygen,.........	0·571429	0·727273

Carbon combines with oxygen and metals to produce salts which are termed carbonates and oxalates, the composition of some of which is shown by the following table:

Carbon.	Oxygen.	Radical.		Salts produced, and their Names.	
3	8	0·25	Hydrogen	11·25	Dried Oxalic Acid
3	8	6·	Sodium	17·	Oxalate of Soda.
3	12	12·	Sodium	27·	Carbonate of Soda
3	8	5·	Calcium	16·	Oxalate of Lime
3	12	10·	Calcium	25·	Carbonate of Lime
3	8	26·	Lead	37·	Oxalate of Lead
3	12	52·	Lead	67·	Carbonate of Lead.

A comparison of the above table with the table of the sulphates, given at page 71, will show that the oxalates are formed in the same manner as the sulphates; that is to say, that the same relative proportions of oxygen and metal which form a sulphate with 4 parts of sulphur, form an oxalate with 3 parts of carbon. Thus :—

Lead.	Carbon.	Sulphur.	Oxygen.	Salts produced.
26	3		8	37 Oxalate of lead
26		4	8	38 Sulphate of lead
Hydrogen.	Carbon.	Sulphur.	Oxygen.	Salts produced.
0·25	3		8	11·25 Oxalic acid
0·25		4	8	12·25 Oil of vitriol

I point out this analogy the more readily, that many chemical books contain a deal of nonsense about a pretended complexity in the composition of the oxalic acid and the oxalates.

Carbon combines with nitrogen to form cyanogen, the composition of which is as follows :—

	By Volume.	By Weight.	Result. Vol.	Spec Gravity.
Carbon,.........	1	3	1	6·5
Nitrogen,......	1	3·5		

Carbon combines also with hydrogen (which see), with chlorine, and other elements.

Carbonic Oxide Gas.—Colourless, tasteless, of a weak but peculiar odour, burns with a blue flame, does not support the combustion of other bodies, cannot be breathed, little animals die in it immediately, specific gravity 3·5, that of oxygen being 4·0.

Production of Carbonic Oxide Gas.—Boil oxalic acid with oil of vitriol in a glass tube. Apply a light to the mouth of the tube, and *a blue flame* will be produced, arising from the combustion of the carbonic oxide gas produced by the decomposition of the oxalic acid.

The gas disengaged in this process is a mixture of carbonic oxide and carbonic acid gas. If the mixture is passed through lime-water, or shaken with it in a bottle, the carbonic acid gas is absorbed, and the other gas left pure.

Carbonic Acid Gas.—Colourless, slightly odorous, sharp taste, incombustible, does not support the combustion of burning bodies, reddens wet litmus paper feebly, but the redness disappears in the air; occasions death when breathed in a pure state; specific gravity 5·5, that of oxygen being 4·0; by cold and pressure, is reduced to the liquid state. It is slightly soluble in water.

Popular remarks on Carbonic Acid Gas.—Carbonic acid gas is extricated in most common cases of effervescence, as when vinegar, or any other acid, is poured upon chalk, marble, or alcaline carbonates. It is produced by fermentation, is formed during many instances of combustion, and by the respiration of animals. It is found in mines, mineral waters, and various other situations; giving rise to many interesting phenomena.

This gas, being much heavier than common air, always keeps its place over the surface of a fermenting liquor, till it rises as high as the edge of the tub or vat which contains it, and then it flows over and descends to the floor: to prove this, hold a lighted candle a few inches above the top of the vat, nothing will take place: next, hold the candle just over the liquor within, and below the top of the vat, upon which the light will be extinguished. The heaviness of this gas is the reason, too, why, when the vat is emptied of the liquor, the gas for some time occupies the bottom of it, so that it is unsafe for the workmen to go down to clean it. This is well known to labourers in breweries, who never descend into the vats before they have tried the purity of the air in them by lowering a candle. If the candle is not extinguished, they know that they may descend with safety; that is a certain sign that the carbonic acid gas has escaped.

After wine or beer is bottled, the fermentation still goes on, though in a much slower degree, and in wine a deposition of tartar takes place. The carbonic acid gas now extricated, being unable to escape, is absorbed by the liquor, and gives to it that briskness and pleasant sharpness which is so far preferable to the flat, insipid taste which all wines have when first made.

In bottling every kind of wine, cider, beer, or other fermented liquors, great care should be paid to the corking. The gas, as it is formed, exerts great force to escape, and if the cork does not fit very accurately, will be sure to find its way out. The liquor will then never acquire the briskness and sharpness that it ought to do; for as the briskness of all such liquors depends upon the presence of carbonic acid gas, they will always prove flat and insipid when the gas is allowed to escape.—It is much better to lay bottled liquor sidelong than upright, for then the gas must not only pass through the liquor before it can escape, but the cork is kept wet and swelled, and is much less liable to decay.

Carbonic acid gas is produced in abundance when charcoal is burned; and it is owing to their not being aware of this production of life-destroying air, that many persons have been killed by going to sleep in rooms where charcoal fires were alight.

Production of Carbonic Acid Gas.—Put a lump of chalk into a tumbler half full of water, and add a little muriatic acid. A strong effervescence will take place, in consequence of a rapid disengagement of carbonic acid gas. If you pour muriatic acid over a considerable quantity of pounded chalk, the resulting effervescence will be very great. In trying this experiment, put the glass containing the chalk in the middle of a large dish.—When charcoal is burned in oxygen gas, the oxygen is converted into carbonic acid gas (see farther on).

To collect Carbonic Acid Gas.—Half fill a Woulfe's bottle (p. 46) with water; put a few lumps of chalk or some pounded marble into it. To one neck affix a cork with the tube-funnel (p. 48), in such a manner that the point of the tube dips into the water contained in the bottle. To the other neck fix a gas-tube (p. 47), in such a manner that the tube passes but just through the cork into the bottle. Let the other end of this tube pass into the jar in which the gas is to be collected, as is shown at page 49. Instead of the Woulfe's bottle, the gas-bottle depicted at page 48 may be used. When the apparatus is fitted together in the manner just described, it is only necessary to pour muriatic acid down the tube-funnel to produce carbonic acid gas in abundance.

Liquid Carbonic Acid.—This name is sometimes given to a solution of carbonic acid gas in cold water, a liquid that can be employed as a means of detecting lime in solution. It is prepared in the way described at page 53, or as follows. Fill a quart bottle with carbonic acid gas, pour into it half a pint of pure water, cork it securely, and shake it violently for a few minutes. Let it now remain for a quarter of an hour, cork downwards, and then shake it again. Continue to do this for three hours, at the expiration of which time, the water will be very strongly impregnated.

Cyanogen.—A compound of carbon and nitrogen, in the proportions given at page 85. Gaseous at common temperatures, but reducible to the liquid state by cold and pressure; reddens wetted litmus paper; has a penetrating odour; burns with a purple flame; cannot support combustion; is soluble in water.

Preparation of Cyanogen Gas.—Take cyanide of mercury, dry it at a gentle heat, put it into a tube-retort, and heat it gently with a spirit-lamp. Cyanogen gas issues from the beak of the tube, and may be burned there, producing a purple flame. If you want to collect it, you must do so without a water-trough.

It is dangerous to make experiments upon this gas.

ANTIMONY.

Antimony is a metal of a silver-white colour, with a strong metallic lustre and a leafy structure. It is brittle, and easy to powder. When heated, it readily fuses. If excluded from air during the operation, it volatilises only in a very slight degree; if ignited in the open air, it remains red hot for some time after removal from the fire, and produces a thick, white smoke of oxide of antimony, which gradually forms a mass of shining crystals on the face of the residual antimony. If a morsel of antimony is ignited on charcoal before the blowpipe, the fused metallic lead exhibits a net-work consisting of crystallised oxide of antimony. If the heat is sustained, the antimony volatilises completely in the state of oxide. If the hot bead of antimony is thrown from the charcoal to the floor, it parts suddenly into numerous smoking fragments.

Hot nitric acid converts antimony into an insoluble oxide of antimony. Muriatic acid does not dissolve antimony. Aqua regia dissolves antimony completely; the resulting solution gives a white precipitate upon being mingled with water. Chlorine gas passed over warmed antimony produces liquid chloride of antimony. A variety of useful alloys have antimony for one of their constituents: the metal for printers' types, that on which music is engraved, and pewter, belong to this class. Antimonial preparations serve also as paints and medicines.

Antimony forms many compounds with oxygen, sulphur, and chlorine, combined in various proportions, of the varieties of which it is by no means easy to get a precise account. I shall notice a few of them.

Protoxide of Antimony.—Prepared by igniting antimony in the open air, or by boiling it in a mixture of nitric acid and diluted sulphuric acid. It is white, turns yellow when heated, fuses, and, on cooling, forms a greyish crystalline mass. It sublimes in crystals when heated in close vessels; is easily reduced when ignited with charcoal.

Native Sulphuret of Antimony.—Lead-grey, compact, fibrous, sometimes found in prisms. Fuses in close vessels without change. Dissolves in boiling muriatic acid, under disengagement of sulphuretted hydrogen gas. An equivalent sulphuret of antimony can be prepared by melting antimony with sulphur. It is employed in the preparation of sulphuretted hydrogen gas.

Chloride of Antimony.—A soft solid, easily liquified by heat, and giving crystals on cooling. Produced by throwing powdered antimony into a jar of chlorine gas, an operation attended by combustion.

Bichloride of Antimony.—A transparent, volatile, fuming liquid, produced by passing dry chlorine gas over heated metallic antimony.

TELLURIUM.

Tellurium has a strong metallic splendour, and the colour of silver; it is brittle, and easily fusible. Excluded from air and heated, it volatilises; heated in the air, it forms a white smoke, which is oxide of tellurium. Heated on charcoal before the blowpipe, it burns with a vivid blue flame. It dissolves in nitric acid, but not in muriatic acid; in aqua regia, but not in pure potash.

TANTALUM.

Tantalum is a black powder, which burns in the air to tantalic acid. Hydrofluoric acid is its only solvent. It becomes oxidised when fused with pure or carbonated alcalies.

TITANIUM.

Titanium possesses a characteristic rosy copper-red colour, accompanied by a brilliant metallic splendour. It also forms a dark indigo-blue powder. It is found in iron furnaces, crystallised in cubes. The crystals are very hard, brittle, almost infusible, and not volatile. They are not acted on by acids, but are oxidised when fused with nitrate of potash, particularly if borax and carbonate of soda are added. The black powder dissolves in nitric acid.

SILICIUM.

Silicium is a dark-brown powder, without metallic lustre. When heated in the air, it burns on the surface to silicic acid (silica), which coats the unburned silicium. The residue can be dissolved only by a mixture of nitric acid and hydrofluoric acid. When silicium is mixed and heated with carbonate of potash, it is readily oxidised at a temperature lower than a red heat. Chlorine gas passed over heated silicium produces volatile chloride of silicium.

Silicium is a very important substance in the mineral kingdom. With oxygen it forms silica; with oxygen and hydrogen it forms hydrate of silicic acid; with oxygen and metals it forms silicates.

Silica.—A white powder, insoluble in water, infusible, inodorous, tasteless, gritty. Native rock-crystal consists of silica nearly in a state of purity. Quartz, flint, and other sandy minerals, consist of silica in various states of impurity. Siliceous stones are harder than window glass, but softer than the diamond.—To prepare silica, transparent specimens of rock-crystal are ignited, thrown, while red-hot, into water, to render them brittle, and then reduced to powder in an agate mortar.

HYDROGEN.

Hydrogen is a colourless, inodorous gas, which, however, has often a disagreeable smell, in consequence of the presence of slight impurities. It is combustible, and burns with a flame which, in strong daylight, is scarcely visible. When oxygen gas and hydrogen gas are mingled and inflamed, they burn with violent explosion. The gases disappear in the proportion of two volumes of hydrogen to one volume of oxygen. The product is water. Hydrogen gas is the lightest of all known gases. Its specific gravity is 0·25 or $\frac{1}{4}$, the specific gravity of oxygen gas being set at 4, and that of common air at 3·6. A cubic inch of hydrogen gas (barometer 30 inches, thermometer 60°) weighs 0·02125 grain. Hydrogen gas does not support combustion, nor is it fit for the respiration of animals. As a constituent of the material world, it is of prodigious importance, forming, notwithstanding its extreme lightness, a ninth part by weight of all water, and being an ingredient in a vast number of energetic chemical compounds.

The COMPOUNDS WHICH CONTAIN HYDROGEN are of two kinds: first, those which are found ready-formed in the animal and vegetable kingdoms; secondly, those which are found in the mineral world, or which can be produced by the art of man. I shall first treat of the latter, then of the former sort.

CHEMICAL COMPOUNDS OF HYDROGEN:—

With *Oxygen* it combines to form two distinct compounds, namely, water and peroxide of hydrogen:—

	Water.		Peroxide of Hydrogen.	
	Volumes of Gas.	Weight.	Volumes of Gas.	Weight.
Oxygen,	1	4·0	1	4·0
Hydrogen	2	0·5	1	0·25

With *Sulphur* it forms sulphuretted hydrogen gas:—

	Volume.	Weight.	Resulting Volume.	Specific Gravity.
Sulphur,………	1	4·	1	4·25
Hydrogen,……	1	0·25		

With *Nitrogen* it forms ammonia:—

	By Volume.	By Weight.	Resulting Volume.	Specific Gravity.
Nitrogen	1	3·5	2	2·125
Hydrogen	3	0·75		

With *Chlorine* it forms muriatic acid gas :—

	Volume.	Weight.	Resulting Volume.	Spe. Gravity.
Chlorine,.........	1	9·	2	4·625
Hydrogen,.......	1	0·25		

A cubic inch of this gas weighs 0·393125 grain.

One part of it contains 0·972973 chlorine + 0·027027 hydrogen.

With bromine it forms hydrobromic acid; with iodine, hydriodic acid; with fluorine, hydrofluoric acid; with phosphorus, two kinds of inflammable gas, differing in properties, yet alike in composition.

With *Carbon* it forms a variety of compounds, several of which are gaseous, and composed as follows :—

	By Volume.		By Weight.		Result. Volume	Specific Gravity
	Carb.	Hydrog.	Carb.	Hydrog.		
Bicarburet of Hydrogen	1	1	3·0	0·25	$\frac{1}{3}$	9·75
Olefiant Gas...............	1	2	3·0	0·5	1	3·5
Gas of Marshes	1	4	3·0	1·0	2	2·0

With electro-negative elements, such as chlorine, sulphur, &c., both *with* and *without* oxygen, it forms acids; with electro-positive elements, such as metals, in connexion with oxygen, it forms alcalies and hydrates. No manifestation of alcaline or acid properties takes place without the presence of hydrogen. No compound of hydrogen with an electro-negative element is alcaline. No compound of hydrogen with an electro-positive element is acid. No compound of oxygen with either electro-positive or electro-negative elements, free from hydrogen, is either acid or alcaline. In short, acidity and alcalinity are properties capable of manifestation only in the presence of hydrogen.

The table on the opposite page exhibits the constitution of a variety of compounds in which hydrogen is an essential constituent. I have inserted a few compounds which contain no hydrogen, for the purpose of contrasting their constitution with that of particular hydrogen compounds somewhat related to them.

Hydrogen.	Oxygen.	Other Elements.	Name and Weight of Resulting Compounds.
0·25	4·0	———	4·25 Peroxide of Hydrogen
0·5	4·0	———	4·5 Water
0·25	—	4·0 Sulphur	4·25 Sulphuretted Hydrogen Gas
0 25	—	9·0 Chlorine	9 25 Muriatic Acid Gas
0·25	12·0	9·0 Chlorine	21·25 Hydrate of Chloric Acid
0·25	12·0	3·5 Nitrogen	15·75 Hydrate of Nitric Acid
—	20·0	7·0 Nitrogen	27·0 Dry Nitric Acid (chimerical)
—	12·0	3·5 Nitrogen 10·0 Potassium	25·5 Nitrate of Potash
0·25	8·0	3·5 Nitrogen	11·75 Hydrate of Hyponitrous Acid
0·25	8·0	4·0 Sulphur	12·25 Hydrate of Sulphuric Acid
—	8.0	4·0 Sulphur 10·0 Potassium	22·0 Sulphate of Potash
0·25	8·0	3·0 Carbon	11·25 Effloresced Oxalic Acid
0·25	—	3·0 Carbon	3·25 Bicarburet of Hydrogen
0·5	—	3·0 Carbon	3·5 Olefiant Gas
1·0	—	3 0 Carbon	4·0 Gas of Marshes
0·25	—	3·0 Carbon 3·5 Nitrogen	6·75 Prussic Acid
0·75	—	3·5 Nitrogen	4·25 Ammonia Gas
1·0	—	3·5 Nitrogen	4·5 Ammonium (Imaginary)
1·0	—	3·5 Nitrogen 9·0 Chlorine	13·5 Sal ammoniac (chloride of ammonium)
1·0	12·0	7·0 Nitrogen	20·0 Nitrate of Ammonia
0·25	4·0	10·0 Potassium	14·25 Caustic Potash
0·25	4·0	5·0 Calcium	9·25 Hydrate of Lime (slaked lime)
—	4·0	10·0 Calcium	14·0 Anhydrous Lime (quick lime)
0·25	4·0	2·0 Silicium	6·25 Hydrate of Silica
—	4 0	4·0 Silicium	8·0 Silica

I beg to call the student's particular attention to this table, and to the following two memoranda :—

I. The difference between an ACID (namely, a *hydrated* acid) and a SALT, is this :—The former contains one combining proportion or 0·25 parts of *hydrogen*, where the latter, *instead* of this hydrogen, contains exactly one combining proportion of a metal, *all other constituents*, both of the acid and salt, *remaining the same*.

EXAMPLES :—

4 Sulphur, 8 Oxygen, 0·25 Hydrogen, = Sulphuric Acid.
4 Sulphur, 8 Oxygen, 10·0 Potassium, = Sulphate of Potash.
3·5 Nitrogen, 12 Oxygen, 0·25 Hydrogen, = Nitric Acid
3·5 Nitrogen, 12 Oxygen, 10·0 Potassium, = Nitrate of Potash.
3 Carbon, 8 Oxygen, 0·25 Hydrogen, = Oxalic Acid.

3 Carbon, 8 Oxygen, 10·0 Potassium, = Oxalate of Potash.
9 Chlorine, 0·25 Hydrogen, = Muriatic Acid.
9 Chlorine, 10·0 Potassium, = Muriate of Potash.
9 Chlorine, 12 Oxygen, 0·25 Hydrogen, = Chloric Acid.
9 Chlorine, 12 Oxygen, 10·0 Potassium, = Chlorate of Potash.

Numberless illustrations of this sort could be given, but these suffice to confirm the above proposition, viz., that the hydrated acids are simply salts of hydrogen. The reason why I wish to direct the student's attention to this subject is, that in every chemical book which falls into his hand, he will find the absurd proposition gravely inculcated, that the *salts* CONTAIN *acids*; that, for example,

Sulphate of potash *contains* sulphuric acid,
Nitrate of potash *contains* nitric acid,
Oxalate of potash *contains* oxalic acid,
Muriate of potash *contains* muriatic acid,
Chlorate of potash *contains* chloric acid;

all of which assertions are destitute of the smallest foundation in truth, and are, indeed, self-evident impossibilities. In fact, it would be quite as correct to say, that sulphuric acid contains sulphate of potash, as to say that sulphate of potash contains sulphuric acid. The truth is, that they are two distinct compounds, each containing the same number of constituent atoms, but neither of which does, or can, form *part* of the other.

II. The difference between a *hydrate of a protoxide of a metal* (such as slaked lime) and an *anhydrous protoxide of a metal* (such as quick lime), is this:—The former contains a combining proportion of hydrogen where the latter contains a combining proportion of a metal. The difference between a hydrated protoxide and an anhydrous protoxide is, therefore, the same as the difference between an acid and a salt. In both cases, one of the compounds contains a combining proportion of hydrogen, which is replaced in the other by a combining proportion of a metal.

EXAMPLE:—

5 calcium, 4 oxygen, 0·25 hydrogen, = hydrate of lime.
10 calcium, 4 oxygen, 0·0 hydrogen, = anhydrous lime.

This is the case with all the metallic protoxides. It is needless to incumber the reasoning with illustrations.

These hydrates of protoxides contain no water, for they contain but one proportion of hydrogen, whereas water contains two proportions. Yet they give off water when exposed to heat, and they produce nothing else than anhydrous protoxides. There is no difficulty in ascertaining how this effect is produced, or in showing the source of the constituents from which the water is *produced* by this experiment.

CONSTITUENTS OF TWO PROPORTIONS OF HYDRATE OF LIME:—	WHAT THEY PRODUCE BY EXPOSURE TO HEAT:—	
0·25 × 2 = 0·5 Hydrogen	0·25 × 2 = 0·5 Hydrog.	4·5 water
4·0 × 2 = 8·0 Oxygen	4·0 × 1 = 4·0 Oxygen	
5·0 × 2 = 10·0 Calcium	4·0 × 1 = 4·0 Oxygen	14·0 lime
	5·0 × 2 = 10·0 Calcium	
9·25 × 2 = 18·5 Hydrate	18·5	18·5

The foregoing observations force some remarkable conclusions upon our notice; namely, that hydrogen, in combination with strong electro-negative elements, produces acid compounds, but that in combination with strong electro-positive elements, it produces alcaline compounds. Yet to these general rules, the ever-singular ammonia presents an exception. By acid compounds, I mean such as taste sour and redden blue litmus paper. By alcaline compounds, I mean such as taste like common potash, and which change the yellow colour of turmeric to brown. When no hydrogen is present, there is no manifestation either of acid or alcaline properties. If, therefore, any substance deserved to be called the *acid-former* or the *alcali-former*, that substance is hydrogen. Yet no man, ungifted with foreknowledge, should presume to apply general names to individual substances.

The greater part of the numerous acids and salts which contain oxygen as a constituent, appear to fall within the limits of the following scheme, in which M signifies the *metal* or *hydrogen* (i. e. the electro-positive constituent), R the *radical* of the salt, and O the *oxygen*; the figures denoting the number of atoms present of the element after which they stand:—

Class 1. $M^1 R^1 O^1$
2. $M^1 R^1 O^2$
3. $M^1 R^1 O^3$
4. $M^1 R^1 O^4$

Class 5. $M^2 R^1 O^3$
6. $M^1 R^2 O^3$
7. $M^2 R^2 O^3$

Examples :—

Class 1.—$M^1\ R^1\ O^1$. Silicates. Many of the salts in which both M and R are metals, Hyposulphites.

Class 2.—$M^1\ R^1\ O^2$. Sulphates, Oxalates, Chlorites, Hyponitrites, Manganesates, Seleniates.

Class 3.—$M^1\ R^1\ O^3$. Nitrates, Hyposulphates, Chlorates, Iodates, Bromates.

Class 4.—$M^1\ R^1\ O^4$. Perchlorates.

Class 5.—$M^2\ R^1\ O^3$. These salts are a species of basic salts of class 2, i. e. $MO+RO+MO$. Carbonates.

Class 6.—$M^1\ R^2\ O^3$. These salts are a species of acid salts of class 2, i. e. $MO+RO+RO$. Many metallic salts.

Class 7.—$M^2\ R^2\ O^3$. Sulphites, Selenites.

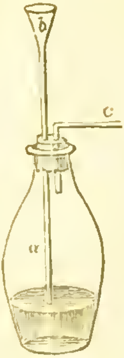
The super- or bi- *salts* commonly contain an atom of a metallic salt and an atom of a hydrogen salt. Thus, bisulphate of potash contains an atom of sulphate of potash and an atom of oil of vitriol ; binoxalate of soda contains an atom of oxalic acid and an atom of oxalate of soda.

I think that the word acid, taken as a substantive name, ought to be disused in chemistry. It has done mischief. It ought to be employed only as denoting a quality. Many salts are acid, as well as the compounds more usually termed acids ; and, by the rule of contrary, many compounds now called acids, have no acid properties ; for example, silicic acid.

I shall close this short discussion of the nature of acids and salts by adding a table, showing the comparative composition of the oxalates and carbonates ; and I shall do this, for the sake of perspicuity, in reference to the salts of a single metal :—

Carbon.	Oxygen.	Hydrogen.	Sodium.	Weight of the Compounds Produced.
3	8			11·00 Carbonic acid
3	8	0·25		11·25 Oxalic acid
3	8		6	17·00 Oxalate of soda
6	16	0·25	6	28·25 Binoxalate of soda
3	12		12	27·00 Carbonate of soda
3	12	0·25	6	21·25 Bicarbonate of soda

Preparation of Hydrogen Gas.—Put iron nails, or wire, or granulated zinc, into a mixture of sulphuric acid and water,



say one ounce of metal, one ounce of acid, and five or six ounces of water. Employ a Florence flask, or any other kind of bottle or retort. The gas is disengaged without the application of heat. If you wish to dry the gas, make it pass through a tube containing lumps of chloride of calcium. This tube may be connected with the gas tube by means of a cork. The gas can be conveyed from the other end of the tube containing the chloride of calcium, by a third tube. It may be collected over water, in the manner described at page 49.

In this operation the sulphuric acid (composed of oxygen 8, sulphur 4, and hydrogen 0·25) is decomposed, and every 0·25 by weight of hydrogen that escapes determines the combination of 7·0 by weight of iron with the remaining constituents, and produces 19·0 by weight of sulphate of iron. The water with which the acid is mixed is not acted upon in this experiment. Its only use is, probably, to bring the iron and acid into contact, and to dissolve the new sulphate as it is formed.

PARTICULAR DESCRIPTION OF THE COMPOUNDS OF HYDROGEN :—

WATER, a fluid of which the most useful properties are universally known, and properly appreciated. Without it, neither vegetable nor animal life could be supported.

When *pure*, it is perfectly transparent, tasteless, inodorous, and not liable to change. At 32° of Fahrenheit's thermometer, it freezes, and forms *ice*. At 212°, it boils, and is converted into STEAM, in which case it expands from 1 volume to 1700. In other words, a pint of water produces 1700 pints of steam. Water is nearly incompressible. It is composed of 4·0 parts of oxygen and 0·5 of hydrogen, and can be decomposed so as to produce these elements. It is capable of dissolving many substances, and producing *solutions*. It enters into various solid compounds, in the state of *water of crystallisation*. Rain water is the purest we see in nature. Spring water has always some mineral impurities. By distillation it is freed from whatever contaminates it.

The method of obtaining pure water, has been described at page 62.

SULPHURETTED HYDROGEN is a *gas*, whose component principles are hydrogen and sulphur. Its specific gravity is 4·25, being considerably higher than that of common air. It burns (when lighted) with a pale blue flame, depositing sulphur. It does not support combustion. Its smell is extremely fetid, resembling that of rotten eggs. Its taste is sour. It reddens vegetable blues. It is absorbed by water. It can be reduced to the liquid state by pressure. Of all the gases, sulphuretted hydrogen is perhaps the most deleterious to animal life. A dog of middle size is destroyed in air, containing only the 800th part of its bulk of it. Indeed, it has been proved, that to kill an animal, it is sufficient to make the sulphuretted hydrogen act on the surface of its body, when it is absorbed by the inhalents. Yet, to the presence of this gas, is chiefly owing the beneficial medicinal properties of Harrowgate, Aix-la-Chapelle, and some other mineral waters. Sulphuretted hydrogen is employed by the chemist as a re-agent. It unites with metallic sulphurets to form hydrosulphurets.

Preparation of Sulphuretted Hydrogen Gas.—I. Mix 2 parts of iron filings with 1 part of sublimed sulphur; add as much water as will make the whole into a thick paste. Heat the mixture for some time, then add strong muriatic acid, and apply heat. Use a flask or Woulfe's bottle as a retort.

II. Mix pulverised grey sulphuret of antimony with four or five times its weight of strong muriatic acid. It is necessary to apply a slight heat to the bottle which contains the mixture. The gas may be collected over hot water, salt and water, or mercury.

Liquid Sulphuretted Hydrogen.—Pass sulphuretted hydrogen gas into water, until the water is completely saturated. This test only acts well when it is newly prepared, because the gas rapidly escapes. The bottle which contains it ought always to be retained in an inverted position.

SULPHURIC ACID.—When sulphur is burnt in oxygen gas, and the gaseous combination of sulphur and oxygen is mixed with water, the liquid product is found to possess, in a very eminent degree, the distinguishing properties of acids. This liquid, when concentrated to the specific gravity of

1·845, is termed *oil of vitriol.* It is caustic, and therefore poisonous. It has a powerful action on organic substances, small portions of which give it a brown colour. Its density is nearly twice that of water; for which body it has a strong attraction. When mixed with water, great heat is produced. It abstracts water from the atmosphere. Sulphuric acid is prepared in the large way, by burning sulphur mixed with a large portion of nitre, in closed chambers lined with lead. The nitre furnishes oxygen to the sulphur, and the acid, as it is produced, combines with a quantity of water, with which the floor of the chambers is previously covered. This liquid acid is afterwards distilled, to free it as much as possible from water. The use of sulphuric acid in chemistry, metallurgy, bleaching, dyeing, medicine, and other arts, is very extensive. Some metals dissolve in cold sulphuric acid, and disengage hydrogen gas. Other metals dissolve in hot sulphuric acid, and disengage sulphurous acid gas.

Production of Sulphuric Acid.—Mix eight or ten parts of sulphur with one of nitre, in a small cup, supported over the surface of water in a dish. Ignite the mixture, and place over it a large glass, so as to dip into the water, and form a close vessel. By this process the water in the dish is converted into very dilute sulphuric acid, as may be known by applying the proper tests for that compound. Sulphuric acid is also produced by boiling sulphur in aqua regia.

For *use*, the acid can be bought ready made, in a state of considerable purity. Great care is required in operations performed with this acid. It must not be dropped about carelessly, as it burns all that it touches. It is dangerous to expose it to a boiling heat, as its ebullition is attended with explosive violence. The distillation of this acid cannot safely be undertaken by an unpractised experimenter.

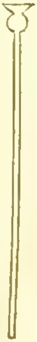
Ammonia.—In the gaseous state colourless, has a powerful stinging odour, is destructive of animal life, has a strong alcaline taste, gives a brown colour to turmeric paper, which vanishes in the air; is reducible by cold and pressure to the state of a thin colourless liquid, dissolves in great quantity in water; very slightly combustible; does not support the combustion of other bodies. Sp. gr. 2·125.

Preparation of Ammonia Gas.—I. Put liquid ammonia into a flask, and heat it. The gas is rapidly disengaged.

II. Take one part of sal ammoniac, and two parts of quicklime, each separately powdered, mix and introduce them into a flask. Apply a gentle heat, and the gas will be rapidly evolved. If this gas is conveyed into water, it is rapidly absorbed: the water acquiring the properties of what is known by the name of *liquid ammonia.* To collect it, therefore, you do not use the water trough, but proceed as directed at page 52.

Liquid Ammonia (to be used as a test).—Buy it, or prepare it by passing ammonia gas into water, as directed, page 53. The stopper of the bottle it is put into, must fit well, and the bottle must be kept in a cool place. It is employed to render acid and neutral solutions alcaline, when a change of state is necessary. It is a test for copper, chloride of silver, and many other compounds.

Nitric Acid.—A colourless liquid; odour, very weak; taste, excessively sour and corrosive; colours litmus red; acts very destructively on organic bodies; communicates a yellow colour to such as contain nitrogen. When concentrated, it abstracts water from the atmosphere. Its specific gravity is about 1·500. Most commonly it is of a yellow colour, in consequence of containing nitrous acid. *Aquafortis* is a weak and impure sort of nitric acid.



Preparation of Nitric Acid.—Ten parts of purified saltpetre are put into a retort, and exposed to heat with 9 parts of oil of vitriol. These ingredients must be put into the retort, without soiling the neck; those precautions being taken, which have been described at pages 19 and 20, and a funnel of the annexed form being employed for the insertion of the acid. You must take care to regulate the heat properly. As the acid passes over into the receiver, the latter must be cooled by the external application of water or wet cloths.

Muriatic Acid Gas.—Colourless, fumes in moist air, taste sour and corrosive, odour pungent and peculiar, extinguishes flame, is destructive of animal life, reddens litmus, is incombustible. Composition, page 92. Capable of reduction to the liquid state by cold and pressure; absorbed in large quantity by water, *i. e.*, 1 volume of water will absorb 480 equal volumes of muriatic acid gas, producing a liquid acid of the specific gravity of 1·2109. This, when pure, is colourless, but owing to impurities the muriatic acid of commerce has usually a straw colour. It is generally obtained from common salt, and hence has been called *spirit of salt.* It is an acid that is much used in the arts and chemical laboratories.

Preparation of Muriatic Acid Gas.—Use the apparatus figured at page 48. Put into the flask 6 parts of dried common salt (chloride of sodium), and pour over it a cold mixture of 5 or six parts of oil of vitriol with one part of water. Employ the heat of a sandbath. This gas cannot be collected over water, in consequence of its ready solubility in that liquid. It can be collected by the method described at page 51, or over mercury.

Explanation of the production of Muriatic Acid in this experiment:

Materials employed.				*Products.*			
6·0	Sodium	15·0	Common salt.	0·25	Hydrogen	9·25	Muriatic Acid.
9·0	Chlorine			9·	Chlorine		
0·25	Hydrogen	12·25	Oil of vitriol.	6·0	Sodium	18·0	Sulphate of Soda.
4·0	Sulphur			4·0	Sulphur		
8·0	Oxygen			8·0	Oxygen		
27·25		27·25		27·25		27·25	

Liquid Muriatic Acid.—In the preparation of this compound, the apparatus described at page 55, is employed in conjunction with the vessel spoken of in the experiment just recited. A good deal of care is required when pure acid is wanted. The vessels must all be cooled externally; the first must contain but little water, the others may be half filled. The acid in the first recipient is always impure.

Acid thus prepared should be colourless, but in general it is slightly yellowish, owing to the presence of iron, or chlorine, or nitrous gas. Its taste is very sour, smell sour and stinging, not so corrosive as sulphuric acid. It boils at a lower temperature than water if concentrated, at a higher temperature if weak. A strong acid is weakened, a weak acid is strengthened, by boiling. There is a certain point at which the acid boils without alteration.

When metals are dissolved in muriatic acid, hydrogen is set free, and metallic chlorides remain in solution. Every 0·25 by weight of hydrogen that is collected, indicates the formation of as much chloride as contains 9·0 by weight of chlorine.

Chloric Acid.—Prepared by adding sulphuric acid to a solution of chlorate of barytes, which throws down sulphate of barytes. It is a colourless acid liquid, not applied to any use.

Hydrofluoric Acid.—This acid is equivalent in composition to muriatic or hydrochloric acid. It is composed of one combining proportion of hydrogen and one combining proportion of fluorine. It contains no oxygen. When the fluorine combines with a metal to form a fluoride, it gives up the hydrogen with which it is combined in the hydrofluoric acid. The fluorides contain one combining proportion of fluorine united to one combining proportion of a metal. Derbyshire fluor spar is a native fluoride of calcium.

Preparation.—Powdered fluor spar, free from silica, is heated with twice its weight of oil of vitriol. The operation needs to be performed in vessels of platinum or lead, because the hydrofluoric acid decomposes glass immediately upon coming into contact with it. Hence it must also be collected and preserved in metallic vessels.

Properties.—Soluble in water, intensely sour, reddens litmus, corrodes and dissolves glass, acts injuriously upon the organs of respiration, the vapours produce pain at the finger ends, drops on the skin produce very painful sores. Used in mineral analyses.

Phosphoric Acid.—When a phosphate is so treated that its metal is got rid of, and an equivalent proportion of hydrogen is substituted in its place, the resulting compound is the hydrate of phosphoric acid. It forms a tough, hard, colourless, and transparent glass, which melts to a syrupy liquid when heated, and sublimes undecomposed at a red heat.

Phosphoric acid, and the phosphates, suffer a good deal of alteration in their properties, when exposed to a red heat, continuing, nevertheless, unaltered in composition. The properties of the pyrophosphates have been detailed by

Dr Thomas Clark, who discovered them, and more recently by Mr Grahame.

PHOSPHURETTED HYDROGEN GAS.—There are two varieties of this compound, alike in composition, but differing in properties. One of them is endowed with the faculty of taking fire spontaneously upon escaping into the atmosphere, the other requires to be set fire to before it can exhibit inflammation.

SPONTANEOUSLY INFLAMMABLE PHOSPHURETTED HYDROGEN is a gaseous compound of phosphorus and hydrogen. Its characteristic property is extreme combustibility: it inflames by merely coming into contact with the atmosphere. A very brilliant white light attends its inflammation in oxygen gas. When brought into contact with chlorine, it detonates with a brilliant green light. It has a very disagreeable smell, resembling that of putrid fish. It combines in a very slight degree with water. It is not acid. Those flashes of light, called by the vulgar *will-of-the-wisp*, and by some *ignes-fatui*, which are often seen in churchyards, and other places where vapours are exhaled from putrifying animal matter, are produced by the formation and inflammation of this gas.

Preparation.—A small piece of phosphorus is put into a little retort, which is then filled with a solution of potash or a milk of lime and water. A long tube is joined to the retort, and a very gentle heat is applied by a spirit-lamp. The tube-neck of the retort is made to dip a little way into water contained in a capsule. When the gas passes over, bubble by bubble, as it rises in the air, it explodes with a small flame, producing elegant wreaths or rings of thick white smoke, which, if the air be tranquil, gradually float away, enlarging in diameter as they go up higher and higher. If a small glass filled with oxygen gas is held over the mouth of the retort, the bubbles, as they rise and explode in the oxygen gas, produce a light of extraordinary brilliancy.

Experimenting with this gas is not free from danger. Sometimes explosions occur in the retort which smash it to pieces. In particular, the exploding of the gas in oxygen is subject to accident, and ought never to be exhibited without putting a wire safe round the glass containing the oxygen gas. Young students must satisfy themselves with the modified experiment described in a subsequent section. See "Fountain of Fire."

SELENIC ACID.—A rare compound, similar, in many respects, to sulphuric acid. Seleniates resemble sulphates.

ARSENIURETTED HYDROGEN GAS.—Inflammable, extinguishes flame, destroys animal life. It is exceedingly dangerous to meddle with it.

CHROMIC ACID.—Composed of chromium, oxygen, and hydrogen. It is of a deep red colour. Its aqueous solution affords crystals by evaporation. The chromates contain chromium, oxygen, and the metals. They are beautifully coloured.

BORACIC ACID.—*Preparation.* Dissolve borate of soda (borax) in hot water, and filter the solution; then add sulphuric acid by little and little, till the liquor has a sensibly acid taste. Put it aside to cool, and a great number of small laminated crystals (scales) will be gradually formed. These are boracic acid. They are to be purified by washing with cold water, which carries off any extraneous soluble body, but leaves the acid, which is very sparingly soluble, almost untouched. When the crystals have been washed, they are to be drained upon brown paper.

Boracic acid acts on blue colours like an acid, but on turmeric like an alcali. The crystals give off water when heated, and fuse to a transparent colourless glass, which is used as a flux in analysis, and as an ingredient of false gems. It is composed of boron, oxygen, and hydrogen. A substance well known by the name of borax, is composed of boron, oxygen, hydrogen, and sodium. Boracic acid is obtained in the form of thin crystals or scales, of a silvery-white colour, which have a greasy feel, no smell, but a very strange taste—being first sourish, then bitterish, cooling, and at last agreeably sweet. It is soluble in water, but only in a slight degree. It is more so in alcohol, and gives to the flame of that body, when burning, a green colour.

CARBURETS OF HYDROGEN:—

I. GAS OF MARSHES.—This gas is produced by the decomposition of organic substances in stagnant waters. It can be collected as follows:—Fill a flask with the marsh water, and, after inverting it in the water, put a wide funnel into its mouth, and stir up the mud at the bottom of the water with a stick, holding the flask and funnel over the place that you agitate. The gas will then rise in bubbles into the flask and displace the water. The gas of marshes thus collected is accompanied by carbonic acid gas, which can be separated, by putting lime-water into the flask, and shaking the mixture.

This gas is also produced in coal mines, and is the much-dreaded *fire-damp* of the mines. When mixed with atmospheric air and exposed to fire, it detonates with extraordinary violence. Many persons have been killed by such detonations, occasioned by the introduction of lighted lamps into the fire-damp. Accidents of this description are prevented by the use of the *Safety Lamp*, invented for this purpose by Sir HUMPHRY DAVY.

Gas of marshes is colourless, void of taste or smell, unable to support combustion or respiration, yet not poisonous; very sparingly soluble in water. It burns freely in the air, exhibiting a bright yellow flame. Mixed with oxygen gas and inflamed, it produces a loud explosion. Its specific gravity is 2, or one-half that of oxygen. It is composed of 4 volumes of hydrogen and 1 volume of carbon, condensed into 2 volumes.

A mixed gas, namely, the *coal gas*, which is now so much employed in lighting our streets and houses, and which contains the gas of marshes, with a large proportion of olefiant gas, and small quantities of sulphuretted hydrogen, carbonic oxide, carbonic acid, &c., may be procured as follows:—Fill the bowl of the largest tobacco-pipe that can be procured with pulverised coal of a good quality, and close the top of it by the application of pipe-clay, or, what is better, a mixture of sand and beer. When the lute is dry, place the bowl of the pipe in a clear fire; in a few minutes, a dense smoke will issue from the stem, which, on the application of a lighted paper, will inflame, and will continue in a state of beautiful combustion as long as any gas continues to be distilled from the coal. The body which will be found remaining in the bowl of the pipe is the substance called *coke*.

When a quantity of coal gas is required for experiment, it can be obtained by attaching a bladder to a common gas jet, and then opening the stop-cock of the pipe.

II. OLEFIANT GAS.—This gas is prepared as follows: Take one ounce of alcohol and four ounces of sulphuric acid. Employ a retort of the capacity of eight or nine ounces. Add the acid to the alcohol, a little at a time, and shake the retort after each addition, to mix the liquids properly. The mixture becomes brown, and, on being cautiously heated, disengages olefiant gas. When but a small quantity of gas is wanted, half the above materials will suffice. This operation requires a good deal of care, for, unless the heat be well regulated, the mixture is very apt to boil over.

A large quantity of this gas is produced when oily substances are exposed to a red heat in close vessels. Thus it is that *oil-gas* is produced, the brilliant illuminating power of which is owing to the large proportion of olefiant gas it contains.

Olefiant gas burns with a rich white flame in common air, consuming a large quantity of oxygen, of which not less than 3 volumes are required to effect the combustion of 1 volume of olefiant gas. When mixed with oxygen gas and inflamed, it produces so violent an explosion that few vessels can stand the shock. It also explodes with chlorine gas. It is composed of 1 volume of carbon and 2 volumes of hydrogen, condensed into 1 volume. Its specific gravity is 3·5, that of air being 3·6.

There are several other compounds of carbon and hydrogen, which, being of minor importance, are passed over for want of room.

OXALIC ACID.—Oxalic acid is a deadly poison, which, in the crystallised state, has much the appearance of Epsom salt—instead of which it has been sometimes taken accidentally, and more than once has proved fatal. The mode of distinguishing oxalic acid from Epsom salt, is explained in another part of this work. The best antidote to a dose of it is an emetic, aided by copious draughts of warm water, containing chalk, or common carbonate of magnesia. Oxalic acid has an exceedingly sharp, sour, but not unpleasant taste; is soluble in water, and possessed of some bleaching properties. The crystals lose their water in the air, and fall into a white powder.

Oxalic acid may be obtained as follows:—Pour 6 parts of strong nitric acid upon 1 part of lump-sugar, in small pieces, previously put into a stoppered retort, to which a receiver is fitted; distill off a considerable portion of the acid, and set the retort aside to cool, when a great number of needle-shaped crystals will be obtained. It is obtained also from the juice of wood-sorrell, and from many other vegetables. Its salts are termed *oxalates*.

The composition of oxalic acid is stated at page 96.

Prussic Acid, or *Hydrocyanic Acid*.—A colourless liquid, of a strong and peculiar taste and odour, resembling those of bitter almonds. It mixes in all proportions with water. Its specific gravity is 0·7. At a low temperature it forms a crystalline mass. It is exceedingly volatile, boils readily, and when vaporised produces a sublimate.

Prussic acid is one of the most powerful poisons. Large animals have been killed by a few drops placed on the tongue. The preparation of this acid is accompanied by considerable danger, in consequence of its ready volatility.

Prussic acid may be obtained readily by making a saturated solution of cyanide of potassium, and dropping into it as much tartaric acid as will precipitate the potassium in the state of cream of tartar. When the precipitate has subsided, the fluid may be decanted, and slowly distilled, with a moderate heat, into a receiver kept cool with water, or pounded ice.

The composition of prussic acid is as follows:—

	By Volume.	By Weight.	Resulting Volume.	Specific Gravity.
Hydrogen	1	0·25	2	3·375
Carbon......	1	3·00		
Nitrogen...	1	3·50		

The difference between prussic acid and the salts called cyanurets, or cyanides, or anhydrous hydrocyanates, or prussiates, is shown in the following scheme, where the cyanides of potassium and iron are taken as examples of the tribe.

	Total Weight	Nitrogen.	Carbon.	Hydrogen.	Metals.
Prussic acid	6·75	3·5	3·0	0·25	—
Prussiate of potash	16·50	3·5	3·0	—	10·0*
Prussiate of iron	13·50	3·5	3·0	—	7·0†

* Potassium. † Iron.

If the prussiate of potash is a cyanide of potassium, the prussic acid is a cyanide of hydrogen.

There is another class of cyanides, sometimes called TRIPLE PRUSSIATES, which are composed of 3 proportions of carbon, 3 of nitrogen, 2 of some one electro-positive element, and 1 of some other electro-positive element. I shall give two examples of these compounds.

	Potassium.	Iron.	Hydrogen.	Carbon.	Nitrogen.	Total Weight.
Ferrocyanate of potash	20·0	7·0	—	9·0	10·5	46·5
Ferrocyanic acid........	—	7·0	0·5	9·0	10·5	27·0

Hence the composition of Ferrocyanic acid is
equivalent to ... *two particles of prussic acid* = 13·5
and .... *one particle of prussiate of iron* = 13·5
27·0

And the composition of Ferrocyanate of potash is
equivalent to *two particles of prussiate of potash* = 33·0
and .... *one particle of prussiate of iron* = 13·5
46·5

Ferrocyanic acid is therefore a triple salt, equivalent to 3 simple prussiates.

SULPHOCYANIC ACID AND THE SULPHOCYANIDES.—These compounds differ in their composition from all the classes of cyanides hitherto enumerated: for example,

Let H = Hydrogen, K = Potassium, C = Carbon, N = Nitrogen,
S = Sulphur,

H C N S = Sulphocyanic Acid.
K C N S = Sulphocyanide of Potassium.

Thus every atom of cyanogen is combined with an atom of sulphur and an atom of *hydrogen* to form the acid, or an atom of a *metal* to form a salt. All the sulphocyanides are constituted in a similar way, and they do not combine together like the other cyanides.—Solutions of this acid are characterised by the property of striking an intense red colour with solutions containing the slightest traces of peroxide of iron. It is a most delicate test.

Silicic Acid.—I have stated the properties of anhydrous silicic acid at page 90, and the composition, both of that compound and its hydrate, are given at page 93. I have only to add here a note respecting the composition of the compounds of silicium that occur in the mineral kingdom.

Composition of the Silicates:—

One particle of silica contains two particles of silicium and one particle of oxygen. When this is decomposed in presence of one particle of water, which contains two particles of hydrogen and one particle of oxygen, the products are two particles of hydrate of silica, containing one particle each of silicium, hydrogen, and oxygen.

As one particle of water contains the same number of elementary particles as one particle of a metallic protoxide, so must the products of the combination of the elements of a metallic protoxide with the elements of silica, produce compounds equivalent in composition with the hydrate of silica, i. e. compounds consisting each of 1 particle of silicium, 1 particle of oxygen, and 1 particle of the metal which was contained in the metallic protoxide.

But the analysis of a vast number of native silicates has shown their composition to be such, that if we consider a particle of a metallic protoxide to be taken from each, the residual silica is in such quantity, that its oxygen bears to the oxygen of the abstracted metallic protoxide the relations of 1 to 1, 2 to 1, and 3 to 1. Thus, then, there are three distinct tribes of silicates, of which Mitscherlich, Berzelius, and other distinguished chemists, deplore that it is impossible, by any decisive experiment, or by any process of reasoning, to determine which is *the* neutral.

Let us, however, see whether the theory adopted in this book leads not to a decision of this long-disputed question.

We will consider potassium to be the electro-positive constituent of the silicates in all the following cases. What is true of the silicates of that metal, will be true of the silicates of all others.

a. One particle of protoxide of potassium contains 4 in weight of oxygen and twice 10 of potassium; we will call this compound the base of the silicate.

b. One particle of silica contains 4 in weight of oxygen and twice 2 of silicium; we will call this compound the ACID of the silicate.

c. The silicate in which the oxygen of the acid bears to the oxygen of the base the relation of 1 to 1, must consist of

$$\left.\begin{array}{ll}\text{Oxygen......} & 8\\ \text{Potassium...} & 20\\ \text{Silicium......} & 4\end{array}\right\}\text{ equal to }\left\{\begin{array}{l}\text{4, or 1 particle.}\\ \text{10, or 1 particle.}\\ \text{2, or 1 particle.}\end{array}\right.$$

This, then, gives a compound equivalent to the hydrate of silica.

d. The silicate in which the oxygen of the acid bears to the oxygen of the base the relation of 3 to 1, must consist of

$$\left.\begin{array}{ll}\text{Oxygen......} & 16\\ \text{Potassium...} & 20\\ \text{Silicium......} & 12\end{array}\right\}\text{ equal to }\left\{\begin{array}{l}\text{8, or 2 particles.}\\ \text{10, or 1 particle.}\\ \text{6, or 3 particles.}\end{array}\right.$$

This compound is equivalent to a double silicate composed of 1 particle of *b.* (silicic acid) and 1 particle of *c.* (silicate of potash).

e. The silicate in which the oxygen of the acid bears to the oxygen of the base the relation of 2 to 1, must consist of

$$\left.\begin{array}{ll}\text{Oxygen......} & 12\\ \text{Potassium...} & 20\\ \text{Silicium......} & 8\end{array}\right\}\text{ equal to }\left\{\begin{array}{l}\text{3 particles.}\\ \text{2 particles.}\\ \text{4 particles.}\end{array}\right.$$

This compound is equivalent to a triple silicate composed of 1 particle of *b.* (silicic acid) and 2 particles of *c.* (silicate of potash).

These triple silicates are equal in the form of their composition, i. e. in the number of elementary particles they contain, and the relationship of these particles—to the triple prussiates spoken of in the preceding section.

In the following table of silicates, K denotes 1 particle of potassium, S, 1 of silicium, and O, 1 of oxygen.

	Total Weight of		
Composition in Particles.	K	S	O
a. Protoxide of potassium = K O K	20		4
b. Silica .... = S O S		4	4
c. Silicate of potash ...... = K O S	10	2	4
d. Double silicate of potash = K O S + S O S	10	6	8
e. Triple silicate of potash = KOS+SOS+KOS	20	8	12

The above limitation of the varieties of silicates to three is not strictly correct, as there are one or two other rare varieties, in which the relation of the oxygen of the base to that of the acid is different from the terms above noted; but as it would be in vain to try to enumerate *all* the varieties, I have limited myself to three, as being sufficient to afford illustrations for making known my ideas of the composition of the silicates. It is only necessary to add, that in all the varieties of the silicates the same modes of combination occur as in the varieties described above. All the silicates which occur in the mineral kingdom are compounds of silicate of silica (S O S) with silicates of electro-positive metals, in which one or more atoms of the electro-negative silicate is combined with one or more atoms of the electro-positive silicate. In the analysis of a silicate, the object to have in view is the determination of the weight of the silicium, of the electro-positive metal or metals, and of the oxygen. These weights, divided by the weight of a single combining particle of each element, give a series of products denoting the number of particles of each element contained in the given silicate.

If the views given in this book respecting the composition of the silicates and other salts were applied to mineralogy, it would have a great effect upon the systematic arrangements of that science. The upholders of the existing systems of mineralogy will do well to examine the foundations whereon their dogmas rest.

CHEMISTRY OF ORGANIC COMPOUNDS.

In living nature, the material elements appear to obey other laws than those they follow in the mineral world. The multitudinous objects of organic structure that strike our senses on every hand, are not more marvellous in variety than in the simplicity and uniformity of their ultimate composition. The atoms whereof all bodies are composed, and which have been detected, in the mineral kingdom, to the number of fifty-four different sorts, are not to be found to the same extent either in vegetable or in animal bodies. If you subject a *plant* to the action of heat, you get no other products than OXYGEN, CARBON, and HYDROGEN; and if you treat *flesh* in the same manner, you get the same elements, with the addition of NITROGEN. These are the primary component parts of all organic bodies, vegetable and animal. And of the remaining fifty constituents of the material world, only a few are found in organic bodies, combined in particular substances, or present in accidental admixture. The bones of animals contain phosphorus and calcium, their blood contains iron; the wood of plants contains potassium; the eggs of birds contain sulphur, the egg-shells, calcium; fish contain phosphorus, and fish-shells both phosphorus and calcium. But these substances are not to be found in all varieties of organic compounds, nor is any other rule to be followed than that the vital power which endues plants and animals with the functions of maintenance and multiplying, works with no other materials than oxygen, nitrogen, carbon, and hydrogen. To these four ingredients the green grass that covers the field, the beasts that graze on it, and man who rules over all, are alike indebted for the substances of which they are made up.

A living body is a chemical workshop, in which a vast number of processes are in simultaneous action, the object of which processes is to *produce* THE LIVING STATE and to *sustain* it. The action is incessant, as life is continuous; and the power of this action is such, that it brings forth products fit to sustain life, and which no human knowledge can contrive or skill can execute. But at a certain period, one of these chemical operations is interrupted, the routine of the life-sustaining processes is destroyed, and death is the result. From the moment that life is extinct, the component parts of organic bodies become subject to the laws of those of inorganic bodies. The acting powers of organisation cease with the departure of the principle of life.

An organic body differs from an inorganic in this, that it has a visible beginning, is gradually developed, arrives at perfection, has its functions first impaired, then stopped, and finally is destroyed—its elements commingling with the inorganic world, wherefrom the vital power had abstracted them; while, on the other hand, the inorganic body appears ready-formed, in full perfection, and so remains through time, a thing incapable of destruction.

True, indeed, the inorganic elements of the organic body are also incapable of destruction—but the peculiar BEING of a given organic body can be irrecoverably destroyed. The living individual, that dies and returns its constituents to its mother-earth, returns not again to life. The existence of a living body is, therefore, not dependent upon its inorganic constituents; it rests on something else—on something which disposes those inorganic elements that are common to all living bodies to bring forth, in some peculiar way, a result predeterminate and proper for each individual.

This SOMETHING, *the power of life*, is no particular property of the inorganic elements. It is no characteristic of a material substance, such as is specific gravity, or impenetrability, or electric polarity. It is assuredly none of these; yet *what* it is, how it arises, and why it ends, we know not. But the inquiry into the nature of this vital power leads to extensive views. We perceive, that if the globe, with its multitudinous elements in their full proportions, destitute only of the power of life, but placed, in all other respects, in its present circumstances, were rolling on in its heavenly course, it might roll on for ever without producing a single human being or a single blade of grass, to beautify and to gladden its surface. A POWER, to us unknown, above our knowledge, perhaps above our faculties, strange even to material nature, has at a certain period brought *this* SOMETHING into the inorganic mass of the solid world. There it works—and works, too, in such a way as to point it out as being no product of accident, but as a power admirable in its mode of action, multifarious in its influences, calculated with the highest wisdom to reach determinate ends, and to produce an incessant—even now unceasing—succession of transient and perishable individuals, which rise out of each other, and in which, by a continued mutation, the destroyed organisation of the preceding furnishes the substance of the succeeding.

But it is not the origin of the vital power which I have here to investigate; it is the products of its operation. Only one other general observation will I make, viz., that when man feels humbled by the knowledge that it is not in his power to *produce living bodies* by experimenting with their inorganic constituents, he may console his vanity with the reflection, that the vital functions of other living bodies are also incapable of producing many substances from purely inorganic materials, and require the products of other living bodies as materials for their processes. Thus, the vegetable nature of one year feeds on the residue of the preceding year; granivorous animals eat plants, and carnivorous animals require flesh for their support, *i. e.* as materials for supporting the chemical processes carried on in each individual. The operation is long by which the constituents of the earth are brought to form part of the animal structure. It is no great wonder that a natural process of years' duration cannot be grasped by man, and compressed into the limits of a brief experiment.

Analysis of Organic Bodies.—I have already observed, that if you burn a bit of wood, it is converted into carbon, oxygen, and hydrogen. In this case, the vegetable is resolved into its ultimate constituents; and if the operation were so performed that you could collect and ascertain the weight of the products respectively, the analysis would be complete. But there is another sort of organic analysis, by which we separate what are called the *proximate* constituents. If you knead flour in your hand, holding it under dropping water, and catching the white liquor that falls down, you separate the flour into two substances, viz., starch, and a fibrous substance, which is not starch. Every living body contains numerous proximate constituents, elaborated by its peculiar organs, some of which constituents are common to many organic bodies, and some found only in particular subjects. Much has been done by chemists in separating and describing the proximate constituents of organic bodies, and still very much remains to do.

Principle upon which the ultimate analysis of organic substances is conducted by modern chemists.—It is to mix the substance for analysis with another substance, that at a certain temperature parts readily with oxygen, such as oxide of copper, and to burn the mixture so as effectually to decompose it.

The *carbon* produces carbonic acid gas.

The *oxygen* produces water.

The *hydrogen* produces water.

The *nitrogen* is set free in the state of gas.

From the *bulk* of the carbonic acid gas, they ascertain, by calculations founded upon its specific gravity and composition, pages 84 and 86, what *weight of carbon* it contains.

From the *weight of the water* obtained, they ascertain the *weight of the hydrogen* contained in the substance.

The *bulk* of the nitrogen gas produced, and which is ascertained by absorbing the carbonic acid gas by potash, and measuring the residue, indicates the *weight of the nitrogen* in the substance.

By adding the weight of the oxygen in the water and the carbonic acid, and deducting the weight lost by the oxide of copper, they find the *weight of the oxygen* in the compound.

As the student would have much greater difficulty in following the practice than in understanding the principles of organic analysis, I pass over the description of its numerous details, referring those who wish for more information to ROSE's *Manual of Analytical Chemistry.*

Classification of Organic Bodies.—The most convenient arrangement of the information we possess on this subject is, into what relates to *vegetable* bodies, and what relates to *animal* bodies.

VEGETABLE CHEMISTRY.

The limits to which I am confined in this work, forbid me to do more than give but a few articles under each head. I shall make the description of organic substances very brief, because they are such as young chemists do not much experiment upon.

VEGETABLE ACIDS.—The most important of these are the mucous, obtained from gum; the suberic, from cork; the camphoric, from camphor; the benzoic, from balsams; the gallic, from galls, &c.; the malic, from ripe fruit; the citric, from lemon and lime juice; the oxalic, from sorrell, and from bodies distilled with nitric acid; the succinic, from amber; the tartaric, from cream of tartar; the acetic, from vinegar. They are all decomposable by heat, and soluble in water. They produce salts, by combining with metallic bases.

ACETIC ACID.—The same acid, that, in a very dilute and somewhat impure state, is called *vinegar.* Its constituent principles are hydrogen, carbon, and oxygen. When pure it is colourless, pungent, acrid, and volatile. It can be concentrated till capable of corroding the skin. Almost all dry vegetable, and some animal substances, when subjected to a red heat in close vessels, yield vinegar copiously. It is also produced by spontaneous fermentation. A very strong vinegar, used for pickling, &c., is now obtained by distilling dry wood in iron retorts. It is called pyroligneous acid. Acetic acid is of great importance, for it is not only extensively used for domestic purposes, but applied to many of the arts. Its salts are called *acetates*.

OXALIC ACID, a vegetable product of considerable importance, has been already described (page 106).

TARTARIC ACID.—This is that which, united to potash, forms what is called *cream of tartar*. It is obtained in crystals, which are soluble in water. It has a very acid and agreeable taste—so that it may supply the place of citric acid, than which it is cheaper. Its salts are called *tartrates*. When you want Tartaric Acid to use as a chemical test, buy it in crystals, and preserve it in that state. When you want a solution, dissolve a few of the crystals in water. The solution is liable to spontaneous decomposition. It is a test for potash, in solutions of which it produces a white precipitate.

CITRIC ACID, is the purified juice of limes or lemons. It is obtained in the form of crystals, which have an extremely sharp taste, are fusible by heat, and very soluble in water. Citric acid is of considerable service in domestic economy, and in some of the arts. Some of its saline compounds (termed *citrates*), are also much used.

MALIC ACID is contained in most acidulous fruits, such as grapes, currants, gooseberries, apples, oranges, in most of which it is associated with tartaric and citric acids.

GALLIC ACID is obtained from various vegetable substances, particularly from nut-galls. It is a crystallisable acid, soluble in 20 parts of water. It has an astringent acidulous taste, and, when heated, an aromatic, though not pleasant, odour. It is extensively used in dyeing, ink-making, and, by the chemist, as a reagent. Its salts are called *gallates*.

TINCTURE OF GALLS.—Digest a bruised nut-gall in a cold mixture of water and alcohol, and after some hours filter the solution. It is the test generally employed for detecting iron, with all the combinations of which it produces a black tinge. It is, likewise, owing to the *tan* contained in it, a good test for gelatin, with which it forms an insoluble precipitate.

Benzoic Acid, is commonly known by the name of flowers of benjamin, a substance obtained by sublimation from gum benzoin. It appears in white needle-shaped crystals, having a bitter taste, and an aromatic odour. It very readily dissolves in alcohol, but is scarcely at all soluble in water. Its salts are termed *benzoates.* Gum benzoin (or benjamin) is a prime constituent of fumigating pastiles.

Vegetable Alcalies.—Since the year 1816, a great number of substances have been detected in plants, which possess properties in a great degree resembling those of the mineral alcalies. For example, they restore the blue colour of litmus that has been reddened by an acid, and they precipitate a great number of metals from solution. They have, in general, an exceedingly bitter and disagreeable taste, and this they communicate to water, even when dissolved in it in inappreciable quantities. Many of them crystallise, and are capable of affording crystallisable salts, by combining with various acids. The most important of these alcalies are the following:—

Morphia, obtained from opium. Forms small colourless shining crystals. Insoluble in water. Its salts are colourless, crystallisable, very bitter, poisonous.

Strychnine, obtained from *nux vomica*, and from the Upas or Poison Tree. Forms very small white four-sided crystals. Its taste is exceedingly bitter and disgusting. Dissolves only in 7000 parts of water, but water containing but the 700,000 part of this alcali is still sensibly bitter. It easily dissolves in alcohol. It produces salts of extreme bitterness. Very poisonous.

Quinine, the basis of Peruvian bark. Forms white cheesy flocks, crystallises with difficulty; dissolves slightly in water; is very bitter. Its salts are remarkable for their bitterness; the crystals have a pearly appearance. *Sulphate of Quinine* is much employed in medicine, in cases where Peruvian bark, in substance, was formerly administered. Persons subject to be nervous or *feverish* find much benefit from taking daily, about two hours before dinner, a pill containing one grain of sulphate of quinine.

Emetine, obtained from *Ipecacuanha.* Yellowish, slightly bitter, very easily fusible, not very soluble in water. Produces vomiting, even with a dose of the sixteenth of a grain.

NEUTRAL VEGETABLE SUBSTANCES, or such as manifest neither alcaline nor acid properties.

STARCH.—Obtained from seeds and roots, particularly wheat, potatoes, horse chestnuts, acorns, &c. An insipid white powder. Insoluble in cold water. Forms an opaque glutinous solution in hot water. Insoluble in alcohol. By boiling in diluted acids, it is converted into sugar, but with nitric acid it forms malic acid and oxalic acid. It is converted into gum, by being roasted. It forms a blue compound with iodine.

To obtain Starch.—Grate potatoes, lay the mass on a sieve, and pass cold water through it. The water runs down milky, and deposits starch in the tub placed below. Pour off the water, wash the starch several times with fresh water, and then dry it in the air. *Sago*, *Arrow Root*, and *Tapioca* are made by exposing moist starch to a gentle heat. Tapioca is obtained from a poisonous root, named Jatropha Manihot.

GUM.—Colourless, tasteless, and inodorous. Does not crystallise. Dissolves in water, forming mucilage. Insoluble in alcohol. There are several kinds of gums; the one most used in the arts is *gum arabic.* Gum exudes from growing trees.

Gum Tragacanth is a sort of gum, differing from gum arabic, in being insoluble in hot water, with which it produces only a soft slime, and not a solution.

SUGAR.—To be found in every vegetable. Is very abundant in, and easily obtained from, the plant called the sugar-cane. Yielded plentifully by grapes and beet-roots. Taste sweet. Crystallises. Soluble in water, alcohol, and nitric acid. When distilled with the latter, yields oxalic acid.

How Sugar is made.—Ripe sugar canes are pressed between iron cylinders, the juice that runs out is mixed with lime, which throws up a scum, from which the juice is drawn off by a cock below. It is then boiled, and continually stirred, till it has acquired a proper consistence. It is transferred to flat reservoirs to cool; and, when nearly cold, is put into large tuns, the bottoms of which are pierced with many holes, closed by stoppers. After twenty-four hours the liquor is stirred, and when the sugar has crystallised, the mother liquor is drawn off and boiled down for re-crystallisation. The sugar is laid in the sun to dry, and then packed in hogsheads for sale.

Molasses or *Treacle* is the mother liquor of the sugar, which has given up all the crystallisable sugar it held. It remains very sweet, but is black and thick.

Sugar refining.—Two parts of sugar, and one part of lime water dissolved to a syrup, are heated, then mixed with ox blood to clear it, filtered, while hot, through a woollen cloth, and boiled down over a coal fire till it is of such a consistence that a drop taken from the pan draws to a thread between the finger and thumb. The fire is then put out, the syrup is drawn off into a cooler, and, while cooling, is transferred into a glazed clay mould of the shape of a sugar loaf. When the syrup is cold, it is stirred with a stick to make it crystallise. The uncrystallisable part is then suffered to flow from the bottom. Numerous other methods of refining sugar are in practice, which want of space hinders my describing here.

Sugar from Saw-Dust.—There are other methods of obtaining sugar besides that of extracting it from fruits and roots in which it exists ready formed. It can be procured by boiling starch in diluted acids, and by pounding in a mortar concentrated sulphuric acid with straw, lumps of linen, pounded bark, or saw-dust. The sugar thus made is the same as that produced by grapes.

GLUTEN.—Obtained from wheat flour. Forms a ductile elastic mass with water. Very slightly soluble in water. It is this substance that gives to flour the property of forming good paste with water.

Pollenin.—Insoluble in most liquids; burns with great liveliness. It is this substance that produces the explosive-like flame which is seen when *lycopodium* is thrown upon a burning body.

FIXED OILS.—The fixed oils which are found in plants occur chiefly in the seeds, though, in the olive, it is the flesh about the kernel that contains the oil. The oils are expelled by pressure, and the oils are purest when the pressure is effected at common temperatures; but heat is necessary to expel the whole quantity of oil, and what is thus prepared is inferior to the cold-drawn oil.

Pure fixed oils have no taste, are slippery between the fingers. They are lighter than water, insoluble in water and alcalies, do not change vegetable colours, form soaps with alcalies, are coagulated by salts, make paper semi-transparent, are readily inflamed. Upon exposure to air they speedily become rancid.

Most fixed oils contain two different sorts of fat:—I. *Stearine*, which is solid at common temperatures, and forms the chief ingredient of suet, butter, and lard. II. *Eläine*, which is fluid, and forms the principal ingredient of thin oils. If fixed oils are exposed to a low temperature, and squeezed between folds of bibulous paper, the stearine is obtained in a separate state. If the greasy paper is then pressed under water, the liquid elaine is also procured in a pure state. The latter substance is well adapted for oiling watch-work, as it does not readily thicken.

The most important fixed oils are linseed, nut, hemp, poppy, castor, croton, olive, rape, colsa; to which may be added, butter of cacao, palm oil, and wax.

Formation of Soap.—When fixed oils are digested in caustic alcalies, they produce a substance which is soluble in water, namely, *soap*. In this case the oils are decomposed, and various *salts* produced, according to the particular kind of oil and alcali employed. The softest soap is oleate of potash, the hardest is margarate of soda, from which the *oleic* and *margaric acids* can be procured by particular processes. Mixtures of different salts are present in most soaps.

VOLATILE OILS form part of all odorous plants. They are generally obtained by distillation, a few only being extracted by pressure. Very different in colour, smell strong and peculiar to each sort, rough to the feel, mostly lighter than water, a few heavier; decomposed by exposure to air; should be kept in small bottles, full, and well corked; the stain they make on paper is driven off by a gentle heat; they dissolve slightly in water, and communicate their odour to it; they dissolve in alcohol, producing *odoriferous spirits* or *essences*, such as Eau de Lavande, Eau de Cologne, &c.

The most important of the volatile oils are as follows:—Turpentine, lemon, bergamott, aniseed, cajeput, juniper, cinnamon, caraway, lavender, clove, neroli, peppermint, rose, bitter almond, citron, chamomile, nutmeg, camphor. Of all these, oil of turpentine is the most useful. It is procured by distilling common turpentine, and, when purified by a second distillation, it is called *spirit* or *essence* of turpentine.

Camphor.—Obtained from a species of laurel tree. Analogous in its nature to volatile oils. Strong smell. Extremely volatile and inflammable. Insoluble in water and alcalies. Soluble in alcohol, oils, acids. Used in medicine.

Resins.—These are volatile oils, peculiarly modified by the action of oxygen. Solid. Melt, when heated. Insoluble in water. Soluble in alcohol, ether, and alcalies. Not crystallisable. Without determinate shape. Often transparent, seldom colourless. By nitric acid, converted into artificial tannin.

I. *Liquid Resins* or *Balsams.*—Copaiba balsam, balsam of Peru, balsam of Tolu, liquid storax, turpentine. II. *Solid Resins.*—Anime, gum benzoin, pitch, copal, dragon's blood, gum lac, labdanum, mastic, sandarac, storax.

Extracts.—Substances formed by digesting dried plants in hot water.

A. *Bitter Extracts.*—Produced in many pharmaceutical operations from the chamomile, wormwood, cascarilla bark, gentian, &c. Also from the aloe, colocynth, rhubarb.

B. *Astringent Extracts. Tannin.*—Taste astringent. Soluble in water. Forms a precipitate with gelatin, which is insoluble in water. This precipitate is formed when skins are *tanned* and made into leather. It is found abundantly in oak-bark and nut-galls, and may be formed (though not economically) artificially.

Skeleton of Plants.—Under this head we may class the substances which act for plants the part that bones do for animals,—these are, 1, the pith; 2, the wood; 3, the bark. These substances are all solid, perfectly insoluble in most liquids, and very readily inflammable.

The vegetable substances described after this are characteristic rather of particular plants, than of plants in general.

Gum Resins.—These are what their name denotes—resins combined with gum or mucilage. Strong smell. Brittle, opaque, infusible. Form milky solutions with water; transparent with alcohol. Caustic alcalies the best solvent; occur in plants in the state of an emulsion.—*Examples:* Gum ammoniac, assafetida, bdellium, galbanum, gamboge, myrrh, olibanum, opium, scammonium.

CAOUTCHOUC, *Indian Rubber.*—A milky glutinous fluid, which exudes from certain trees, and in drying turns black and acquires consistence. Very elastic. Insoluble in water and alcohol. Soluble in ether and in coal-oil. Very combustible. It now comes from South America in the liquid state, and is employed in several English manufactures. According to the analysis of Faraday and Ure, caoutchouc consists of carbon and hydrogen only. By dry distillation it is made to produce an exceedingly light volatile liquid, which possesses the property of dissolving caoutchouc.

VEGETABLE COLOURS.—Living plants sparkle with the most splendid colours. Innumerable shades of green deck the summits of the trees, and clothe the expanse of the meadows. The colours of the flowers vie with those of the rainbow in splendour and in purity. But exclusive of these emblazoned tints, vegetables boast of interior stores of colouring matter, which they yield to the art of man, and permit him to transfer to his garments of wool, of silk, of cotton, and of linen. The knowledge of these colours, and of the methods whereby they can be extracted from the one substance and fixed upon the other, constitutes the ART OF DYEING, one of the most useful of the arts which depend upon chemical principles.

Vegetable colours are destroyed by chlorine, and also by exposure to the sun's light, or to a high temperature.

Red colours.—Madder, safflower, alkanet, sandal-wood, Fernambuc and Brazil wood, logwood, cudbear.

Yellow colours.—Quercitron bark, yellow wood, weld, annotto, turmeric, saffron, yellow matter of safflower.

Green colours.—Sapgreen, (inspissated juice of rhamnus infectoria), coffee berries.

Blue colours.—Litmus, indigo, blue cabbage.

Some of the substances here enumerated contain pure colouring matters, the method of extracting which is well known. It is, nevertheless, impossible, from want of space, to give here the proper details. I must pass over the colouring matters with merely a few short notices, relative to the use of vegetable colours as chemical tests.

Brazil Wood gives a red decoction if boiled in water. Paper stained with it is turned blue by alcalies, and is bleached by chlorine. It is, therefore, used as a test-paper.

Cudbear.—Its solution in water tinges paper a purple-red. This paper is reddened by acids, and blued by alcalies. It is a delicate and most trust-worthy test-paper.

Rose.—Macerate rose leaves, fresh or dried, for 24 hours in alcohol, and squeeze out the solution. Dilute it with water till nearly colourless. It does not keep good long. *Use.*—Acids make the colourless liquor rose-red. Alcalies make it green.

Turmeric is used in making a test for alcalies, (see page 62.) It gives a fine yellow colour to alcohol. The tincture is best prepared by digesting pounded turmeric with strong alcohol, and then diluting the solution with water till it has a bright yellow colour. Alcalies change this yellow colour to a reddish brown. The reddish brown is turned yellow by acids.

Rhubarb.—Digest one part of coarsely-pounded rhubarb with 30 parts of water, and dilute the solution till the colour is bright yellow. *Use.*—Alcalies change the yellow colour to red. The reaction is very delicate.

Tincture of Cabbage.—To prepare this, pour boiling water upon sliced red cabbage, decant the clear infusion (which will be of a fine blue colour) when cold, and mix it with an eighth part of alcohol. Red cabbage leaves may be preserved for a long time, by drying them in a warm place till they are crisp, having previously cut them into small pieces. It is necessary to be provided with some of these dried leaves, because the tincture spoils by keeping. The blue colour of this test is changed to red by acids, and to green by alcalies and alcaline earths. Test papers, stained with the tincture of cabbage, are acted on the same way as the tincture. They are very useful in many experiments, though inferior in delicacy to cudbear or litmus.

b. Pour boiling water upon sliced red cabbage, add a little oil of vitriol, and stir the mixture. Cover it, and keep it hot, but not boiling, for some time. Strain it, and evaporate it to half its bulk. Allow it to settle; then bottle up the clear red liquor, and cork it close. This acid solution will keep for a year, and can, at any time, be made blue by the addition of soda or potash.

LITMUS.—One part of good fine blue litmus, digested with 25 parts of water, gives a concentrated litmus solution. It may be mixed with a little alcohol. The way to make litmus test-papers has been described at page 63. The blue colour of litmus is reddened by all acids, and the reddened litmus regains its blue colour if treated with an alcali. With respect to the delicacy of this test for acids, we are assured, by Pfaff and Fischer, that one part of sulphuric acid reddens 172,300 parts of tincture of litmus, formed of one part of the concentrated tincture, with 25,000 parts of water; and that $\frac{1}{100,000}$ of sulphuric acid in solution, is indicated by litmus. This colour is also reddened by carbonic acid and sulphuretted hydrogen; but exposure of the test to a gentle heat restores the blue colour.

INDIGO SOLUTION.—Put a very small quantity of powdered indigo into a bottle, add a few drops of the most concentrated oil of vitriol, say in the ratio of 1 part by weight of indigo to 7 parts of acid, close the bottle, put it in a warm place, and shake it frequently. Unless the acid be concentrated, and the indigo of the best kind, the solution sought for will not be obtained. Next day dilute the mixture with 40 times its bulk of water, filter it, and preserve the clear blue solution. It is a test for nitric acid, and for chlorine, by which it is rendered colourless.

PRODUCTS OF THE DESTRUCTION OF ORGANIC BODIES.—No sooner is life extinct, in a vegetable or animal body, than the organic band which connected its elements together is loosened, and the various chemical powers that are in continual action at the earth's surface, facilitate the resolution of the compound into such simple or mixed inorganic bodies as its elements may be capable of producing.

The nature and number of the products, resulting from the decomposition of an organic body, depend not only upon the particular nature of the organic body, but upon the method and agents whereby its disorganisation is effected. Such compounds are produced as can best exist under the circumstances in which the ultimate constituents of the disorganised body are set at liberty in juxtaposition.

The *Vinous Fermentation* derives its name from its product, which is *wine.*—When saccharine vegetable matter, accompanied by some other bodies, as fecula, mucilage, &c., are exposed to water and heat, they shortly experience a very striking alteration. An internal commotion takes place; the mass grows turbid; carbonic acid gas is disengaged, in considerable quantity, and, being enclosed in viscid matter, forms on the surface of the liquor a stratum of *yeast.* After a time these appearances cease, and the fermented liquor becomes clear and transparent. It now has lost its sweetness and viscidity, and acquired the vinous taste and intoxicating quality. Thus *wine* is made from the juice of the grape, and thus *beer*, which may be chemically regarded as the wine of grain, is made from malt.

If the fermentation be stopped, by the exclusion of air, before the whole of the carbonic acid gas is evolved, the wine is brisk and sparkling, like Champaign, from the carbonic acid gas imprisoned in it; it is also sweet, like cyder, from the sugar not being completely decomposed.

Sugar alone does not furnish wine, by undergoing fermentation; for, when it is decomposed, its constituents are recombined into two new substances; the one a peculiar liquid substance, called *alcohol,* or *spirit of wine;* the other, carbonic acid gas.

It is to alcohol that fermented liquors owe their intoxicating qualities, and from those bodies it may readily be separated by distillation. Alcohol, when pure, is of a strongly heating nature, very light, inflammable, volatile, and possesses a peculiar odour. It dissolves resins, volatile oils, camphor, and many other substances. It is composed of small quantities of carbon and oxygen, united to a considerable proportion of hydrogen. Of these elements, in different proportions, sugar is also composed. But, though sugar may be decomposed into alcohol and carbonic acid, it is not possible to compose sugar, by uniting carbonic acid and alcohol.—Alcohol which is to be employed as a chemical test ought to be very pure and highly rectified. That which is intended for fuel for lamps may be impure and somewhat weaker, but it must not contain too great a quantity of water, otherwise it is less economical than strong alcohol, inasmuch as its combustion produces a very feeble degree of heat. You may burn pyro-acetic spirit for fuel, if you wish to save your money, and do not object to the smell of the spirit.

Ether, the lightest of all liquids, highly volatile, inflammable, and odorous, is alcohol, deprived of a portion of its carbon. The decarbonisation of alcohol is effected by the action of strong acids on it; and the ether differs in its nature, and is differently named, according to the particular acid that is made use of. Thus nitric acid with alcohol, produces *nitric ether*, and sulphuric acid, *sulphuric ether*.

The *Acetous Fermentation*, is that which produces *vinegar*. It is generally said, that, in this species of fermentation, the product is obtained from liquors which have already undergone the *vinous* fermentation; indeed, vinegar *is* chiefly prepared from wines, but the vinous fermentation is not necessarily preliminary, for vinegar may be obtained from simple mucilage. Common vinegar may be purified and concentrated by distillation, and it is then called distilled vinegar, or acetic acid.

The phenomena of *Putrefaction* is occasioned by the last change, or final decomposition, which vegetables undergo. The putrefactive fermentation is a complete analysis of vegetable substance, during which the constituent elements are all disengaged in the form of *gas*, with the exception of some fixed earthly products, which remain in the state of mould, and are used as a manure.

But the element *nitrogen* is one that is exceedingly favourable to putrefaction; and substances which contain it, or to which it has been added, are decomposed very rapidly. Among the gaseous bodies which are evolved during this process, are some which have peculiar and disagreeable smells; and from the mixture of these proceeds the fetor that accompanies putrefaction.

No substance can enter into the putrefactive fermentation, if inaccessible by moisture and air; we can, therefore, by keeping bodies in a state of dryness, and where air has no access, hinder their putrefying.

Products of the action of Heat.—Many changes are effected in plants by the simple operation of *roasting*. It is by this operation that barley is made into malt, that starch is converted into gum, that coffee is prepared for use, and many other vegetable substances (dandelion root, &c.) are made into a substitute for coffee. By *dry distillation*, we obtain from plants a great diversity of compounds, some common to many plants, others characteristic of particular individuals. Tar, pitch, charcoal, and various gases are produced by this operation. From wood, also, we obtain acetic acid; from coals, naphthaline, coal-tar, ammonia, illuminating gas, &c. By *combustion in the open air*, we produce smoke and soot, of which certain varieties (lamp black) are of great use in the arts. The incombustible part of plants contains their alcaline and earthy constituents, particularly potash and soda.

ANIMAL CHEMISTRY.—The principal primary constituents of animal substances are nearly the same as those of vegetables; but they have less carbon and hydrogen, and far greater quantities of nitrogen, phosphorus, and sulphur. The most important of the immediate materials of animals, which are formed by the combination of these substances, are *gelatin*, *albumin*, and *fibrin*. These three kinds of animal matter form the basis of all the various parts of the animal system: viz. solid, as the *skin*, *flesh*, *nerves*, *membranes*, *cartilages*, and *bones*; and fluid, as *blood*, *chyle*, *milk*, *gastric juice*, *saliva*, *tears*, &c.

GELATIN, or *jelly*, the chief ingredient in skin. It is known in common life under the forms of glue, size, isinglass, jelly, &c. It is a viscid substance, very soluble in water, but not in alcohol; insipid, and without smell; when cold, it congeals into a cohesive tremulous substance, which liquifies again when heated. It forms the base of soups, &c. The union of gelatin with tannin in a skin, constitutes leather.

ALBUMIN is the principal ingredient in the serum of blood and the white of eggs. It is miscible with cold water, but is coagulated by heat, which forms the best test of its presence. It is also coagulated by acids and alcohol; but is dissolved by pure alcalies.

FIBRIN forms the basis of the muscular part of animals. It is an insipid and inodorous substance, having somewhat the appearance of fine white threads adhering together. It is insoluble both in water and alcohol.

Animal matter, although the most complicated of all natural substances, returns to its elementary state by one single spontaneous process, the *putrefactive fermentation.* By this, the substances forming its different parts are slowly reduced to the state of oxygen, hydrogen, nitrogen, and carbon ; and thus the circle of changes through which these principles have passed, is finally completed. Quitting their elementary forms, they entered the vegetable system, thence passed to the animal kingdom, and from that return again to their original simplicity ; soon to re-enter the sphere of organized existence.

I intreat the reader's pardon for dismissing the subject of Animal Chemistry with this brief notice. It is not want of materials which induces me to do so, for I have now before me a work on this division of the science, written by Berzelius, which extends to 700 octavo pages, and abounds in original and interesting researches, all of which I restrain myself from particularising, lest my little book should increase beyond its prescribed limits, or I should be compelled to leave out matter more generally interesting.

OSMIUM.

Osmium commonly forms a black porous powder, which, on being rubbed or fried, appears metallic, and of a copper-red colour. When heated in the air, it volatilises in the state of osmic acid, which diffuses a very penetrating odour, somewhat resembling that of iodine. The fine powder takes fire when heated in the air.—It combines with both electro-positive and electro-negative substances; but its compounds are not such as fall into the way of young students.

GOLD.

Gold has a beautiful yellow colour, which is not tarnished by exposure to air. When reduced to very thin leaves, it appears green by transmitted light. When precipitated in the form of powder it is brown, but becomes yellow and brilliant on being rubbed. Gold is one of the heaviest metals. Its specific gravity is 19·2. It is soft, very malleable, and very ductile. A grain gives a wire 500 feet long, or a leaf of 56 square inches. It requires a strong heat for its fusion, stronger than that required by copper. It is bluish-green in the fused state. It is not volatile, and does not oxidise when heated in the air. It is insoluble in nitric acid, muriatic acid, and sulphuric acid; but it dissolves when heated in aqua regia. The resulting solution is yellow, and contains chloride of gold. It colours the skin purple.

Compounds of Gold.—It readily combines with other metals. Coins contain gold and copper. Gold combines with chlorine, forming a yellow chloride of gold, which can be obtained in crystals. It also produces double chlorides, by combination with chlorine, and with the metallic bases of the alcalies, such as potassium.

To obtain pure Gold.—Add to a solution of gold in aqua regia a solution of green sulphate of iron, as long as precipitation ensues: the precipitate is to be well washed on a filter (first with diluted muriatic acid, and then with pure water), and dried—it is then pure gold.

CHLORIDE OF GOLD.—Mix two parts of concentrated muriatic acid with one part of concentrated nitric acid. The mixture heats, effervesces, and becomes of an orange colour. This is aqua regia, a liquor which has the property of dissolving gold, and producing a solution of chloride of gold. When this is saturated, it has a deep yellow colour, is very caustic, and of an astringent metallic taste. It tinges the skin, and almost all animal and vegetable bodies, and even marble, of a deep and indelible purple. It crystallises from an acid solution in combination with hydrochloric acid, its beautiful golden colour being preserved. The crystals are very soluble in water, and still more so in ether. Decomposition of this salt is effected by light, heat, earths, alcalies, and several metals.

If the *solution* of gold is to be used as a TEST, evaporate it to dryness in a capsule of Wedgewood's ware. Dissolve the dry chloride in spirits of wine. It is a test for tin.

TEST FOR GOLD.—To a diluted colourless solution of chloride of gold, add a few drops of a solution of any salt of tin, or stir the solution of gold with a slip of metallic tin; in either case, the production of a beautiful purple or port-wine colour will be the immediate result. If the mixture is allowed to settle, the solution becomes colourless; a purple powder, containing both gold and tin, being precipitated. This powder is employed in the painting of china, and is called the Purple Precipitate of Cassius.

IRIDIUM.

Metallic Iridium is whitish, brittle, very heavy, more difficult of fusion than platinum, and insoluble in the mineral acids. When a piece of metallic iridium is held in the flame of a spirit-lamp, it soon becomes coated with a vegetation of charcoal. Its compounds are little known. It is found in the ore of platinum.

RHODIUM.

Metallic Rhodium forms a grey powder, which cannot be fused into a mass by the strongest heat that can be applied. It is insoluble in acids, but can be dissolved when used with bisulphate of potash. Occurs in the ore of platinum.

PLATINUM.

Platinum has a greyish-white colour. In the state of fine powder it is grey, and without metallic splendour; but the lustre can be produced by friction. Platinum is the heaviest of all metals. It is harder than copper, but not so malleable as gold and silver. It can be drawn into exceedingly fine wire. It cannot be melted by the heat of a furnace; but it can be fused by means of a blowpipe, supplied with oxygen gas, and directed upon the flame of a spirit-lamp. It can be welded at a white heat. It does not oxidise when heated in the air. Platinum dissolves in hot aqua regia, but not in any simple acid. The solution contains chloride of platinum. When pure alcalies or nitrate of potash is ignited with platinum, the metal is corroded. When brought, in the state of a fine, porous, spongy mass, into a mixture of oxygen and hydrogen gas, it becomes red-hot, and inflames the gas.

Chloride of Platinum.—Mix two parts of concentrated muriatic acid with one part of concentrated nitric acid; dissolve a small piece of platinum in the mixture, and evaporate the solution to dryness in a capsule of Wedgewood's ware. Dissolve the dry chloride in spirits of wine. It is a test for potash and salts of ammonia, with solutions of both of which substances it gives a yellow precipitate.

PALLADIUM.

Palladium resembles platinum in appearance, but is not so heavy. It is malleable and infusible. It becomes blue when heated in the air, and acquires a coat of charcoal when held in the flame of a spirit-lamp. It dissolves in nitric acid and in aqua regia.

SILVER.

Silver possesses a very white colour, and a strong metallic splendour. It is very sonorous, extremely malleable, ductile, and tenacious; harder than gold, but more easily fusible. It is not oxidised by being heated in the air. Its specific gravity is 10·47. It enters into combustion when exposed to the action of a galvanic battery, and gives a brilliant green light. It is alloyed with copper in coins, &c., to make it harder.

Muriatic acid gives a coating of chloride of silver to a mass of silver, but does not act upon the whole of the silver. Nitric acid readily dissolves silver, and produces a solution of nitrate of silver. Diluted sulphuric acid does not act upon silver. Strong and boiling sulphuric acid dissolves it, under disengagement of sulphurous acid, and produces insoluble sulphate of silver.

Compounds of Silver.—The following table exhibits the composition of the most important:—

Silver.		Oxygen.	Weight and Names of the Products.
55·0		4	59·0 Black oxide of silver
27·5	9·0 Chlorine		36·5 Chloride of Silver
27·5	4·0 Sulphur		31·5 Sulphuret of Silver
27·5	4·0 Sulphur	8	39·5 Sulphate of Silver
27·5	3·5 Nitrogen	12	43·0 Nitrate of Silver

Oxide of Silver.—A black powder, obtained by adding a solution of caustic potash to a solution of nitrate of silver. The black oxide precipitates. Heat converts it into silver and oxygen gas. Oxide of silver in combination with ammonia produces *fulminating silver*, a very dangerous substance to experiment upon.

SULPHURET OF SILVER.—The black substance formed when silver is exposed to sulphureous vapours. Obtained in quantity by fusing silver with sulphur.

SULPHATE OF SILVER.—Small, shining, nearly insoluble crystalline needles. It is the white precipitate which appears when solutions of sulphates are added to solutions of silver-salts. To obtain it pure, add an excess of sulphuric acid to a solution of nitrate of silver, filter the solution, and wash the precipitate till the washings do not change the colour of litmus. Boil the edulcorated precipitate in distilled water, allow it to cool, filter the solution, and preserve it. This liquor is a test for chlorides, in solutions of which it produces a white precipitate.

NITRATE OF SILVER.—Put a small quantity of pure silver into a test-glass, and pour over it twice its weight of nitric acid, and twice as much water as acid. The silver will be quickly dissolved, and at the same time nitrous gas will be discharged. The solution, if the metal and acid be both pure, will be transparent and colourless; but if any copper be present, the solution will have a green colour; and if any gold be present, it will be precipitated in the form of a black powder. Should the nitric acid contain any muriatic or sulphuric acid, an insoluble white powder will be formed, which will be chloride or sulphate of silver. Nitrate of silver may be crystallised. The solution is limpid, colourless, heavy, and caustic. It conveys to hair, the skin, and most animal substances, an indelible black colour, and finally destroys them. It forms brilliant transparent crystals, possessed of a very bitter metallic taste; very soluble in water, not deliquescent, decomposable by light, converted by heat into a preparation, which is used in medicine under the name of *lunar caustic.* Very poisonous.

This salt can be obtained in a pure state from a solution containing copper, by evaporating the solution, and exposing the dry residue to a gentle melting heat, which decomposes the nitrate of copper, and leaves insoluble oxide of copper, which can be separated by filtration.

Nitrate of silver in solution is peculiarly adapted to the discovery of muriatic acid and the chlorides. The silver combines with the chlorine of these compounds, and forms a flaky precipitate, which at first is white, but on exposure to the sun's light, acquires a bluish, and finally a black colour. Muriatic acid, consequently, is a test for silver in solution.

CHLORIDE OF SILVER.—Obtained by adding muriatic acid to a solution of any silver-salt. White cheesy precipitate; after drying, a white insoluble powder, which in sunshine turns violet or black. Easily fuses to a yellow transparent liquor, which cools to a grey, crystalline, tough mass, *horn silver*. It is soluble in ammonia. Very easily reduced to the metallic state by contact with water and iron, or water and zinc, or fusion with carbonate of potash.

The ready formation and absolute insolubility of chloride of silver in water, make solutions of silver and of chlorides valuable tests for detecting each other in solution.

IODIDE OF SILVER.—Pale yellow, much like the chloride, but insoluble in ammonia. A reagent for separating iodine from chlorine.

CHROMATE OF SILVER.—Insoluble red powder.

MERCURY.

THIS is the metal commonly called *quicksilver*. Mercury is distinguished from all other metals, by being fluid at the ordinary temperature of the atmosphere. When exposed to intense cold, it freezes to a solid; when boiled, it evaporates as a colourless gas. The colour of mercury is silver-white; it possesses a metallic splendour, and is heavier than silver, its specific gravity being 15·5.

Muriatic acid does not dissolve mercury. Nitric acid dissolves it, either hot or cold. Sulphuric acid does not dissolve it in the cold; but boiling sulphuric acid dissolves it, under disengagement of sulphurous acid gas.

Compounds of Mercury.—With chlorine it forms calomel and corrosive sublimate; with sulphur, it forms cinnabar, or vermilion; with oxygen, it forms red oxide of mercury; with metals it forms amalgams. All the compounds of mercury are either volatilised or decomposed by heat; and all, when distilled with carbonate of soda, give metallic mercury.

OXIDES OF MERCURY.—There are two, both of which are decomposed by heat into mercury and oxygen gas. One of these is a black powder, the other a red crystalline powder, and very poisonous. The first contains twice as much metal as the last, to the same quantity of oxygen.

Sulphuret of Mercury. Cinnabar.—Take 6 parts of mercury and 1 part of sulphur. Melt the sulphur in a crucible over a charcoal fire, pour the mercury into the melted sulphur, and stir the mixture for some time. The blackish-red mass thus produced is afterward to be submitted to sublimation, when it produces a brilliant scarlet mass. Cinnabar burns in the air with a blue flame. It occurs as a mineral.

Sulphate of Mercury.—Prepared by boiling mercury in oil of vitriol, during which sulphurous acid is discharged in abundance (page 71). A white mass, decomposable by water into a soluble acid sulphate, and an insoluble basic sulphate, which is a yellow powder.

Nitrate of Protoxide of Mercury is made by dissolving mercury in cold diluted nitric acid. The saturated solution is ponderous, colourless, and very caustic. It yields large transparent crystals on evaporation. It tinges the skin of an indelible black colour. It gives a black precipitate with ammonia.

Fulminating Mercury.—White, silky needles, which are exploded with extraordinary violence by rubbing, striking, or heating. Used for preparing percussion-caps. Its preparation requires the greatest care, on account of the danger attending an explosion.

To make Fulminating Quicksilver.—Dissolve 100 grains of mercury in an ounce and a half, by measure, of nitric acid, assisting the solution by heat. When the solution is cold, pour it upon two ounces, by measure, of strong alcohol, previously introduced into a small glass retort, and apply a moderate heat till effervescence is excited. (Do not forget that the mercurial solution must be *poured upon the alcohol*, and not the alcohol upon the solution.) A white fume then begins to undulate on the surface of the liquor, and flows through the neck of the retort; and a white powder is gradually precipitated. As soon as any precipitate ceases to form, quickly pour the contents of the retort upon a filter, well wash the powder with distilled water, and cautiously dry it by a heat not exceeding that of boiling water. The immediate washing of the powder is material, because it is liable to the reaction of the nitric acid; and while any of that acid adheres to it, it is very subject to be decomposed by the action of light. From 100 grains of mercury, about 120 or 130 grains of the fulminating powder are obtained.

CALOMEL. PROTOCHLORIDE OF MERCURY.—Sublimed calomel is a white, crystalline, semitransparent, heavy mass, tasteless, insoluble in water, volatile, but not fusible. When obtained by adding common salt to the solution of mercury in cold nitric acid, it forms a heavy white powder. Useful in medicine. Caustic potash gives a black precipitate in its solutions.

PERCHLORIDE OF MERCURY. CORROSIVE SUBLIMATE.—Crystallises from its aqueous solutions in long white crystals, which sublimation converts into a white, transparent, heavy mass. When heated, it melts, boils, and sublimes. It dissolves in water. From the solution, caustic potash gives a yellowish-red precipitate, and ammonia a white precipitate. Corrosive sublimate is prepared by subliming a mixture of sulphate of mercury and common salt. It is extremely poisonous. White of egg is the best antidote.

CYANIDE OF MERCURY. — Colourless, soluble, poisonous crystals, used to prepare cyanogen.

CHROMATE OF MERCURY.—A fine red powder, produced by adding a solution of chromate of potash to a solution of a protosalt of mercury.

COPPER.

COPPER has a peculiar reddish-brown colour and strong metallic splendour. It is very malleable, tenacious, and ductile; harder than silver, but lighter; highly sonorous; requires a very strong heat for its fusion; when violently heated in the air, burns with a vivid green flame. It is not affected by dry air; but air and water together, convert it into a green basic carbonate. It oxidises when heated in the air, and acquires a coating of black oxide of copper, which falls off when the metal cools. It is one of the most useful and most abundant of metals.

Copper does not dissolve in muriatic acid in close vessels. It dissolves partially if air is admitted. Diluted sulphuric acid acts very slightly on copper. Strong and boiling sulphuric acid dissolves it. Nitric acid readily dissolves copper, producing a solution of nitrate of copper.

Copper combines with zinc to form brass, pinchbeck, prince's metal, &c.; with tin, to form bell-metal, bronze, cannon, mirrors, &c.

COMPOUNDS OF COPPER.

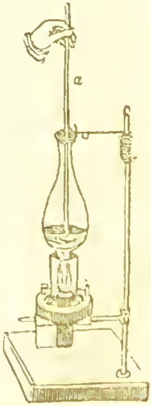
Copper.	Oxygen.	Other Elements.	Weight and Name of the Compounds.
32	4		36·0 Red oxide of copper
16	4		20·0 Black oxide of copper
16		4·0 Sulphur	20·0 Sulphuret of copper
8		4·0 Sulphur	12·0 Bisulphuret of copper
8	8	4·0 Sulphur	20·0 Sulphate of deutoxide of copper
16		9·0 Chlorine	25·0 Protochloride of copper
8		9·0 Chlorine	17·0 Perchloride of copper
8	12	3·5 Nitrogen	23·5 Nitrate of copper

PROTOXIDE OF COPPER.—A red-brown powder.

DEUTOXIDE OF COPPER.—A black powder, obtained by igniting nitrate or carbonate of copper, or by making a plate of copper red-hot, and plunging it in that state into cold water.

These oxides are easily reducible by fusion with charcoal or hydrogen gas, but not when heated alone. The protoxide colours glass red; the deutoxide green, as may be shown by fusing a little of each with borax before the blowpipe.

SULPHURET OF COPPER. *Brilliant Inflammation without the presence of Air!*—The combination of sulphur with many metals takes place under a disengagement of heat and light. If sulphur is fused in a flask, so that the vapour of sulphur fills the whole of the flask, and a strip of sheet-copper is then introduced, the sulphur and copper combine, producing a compound, which instantaneously becomes red-hot, then fuses, and forms a crystalline brittle substance, the sulphuret of copper. A similar result is produced if you mix intimately together, eight parts of copper-filings and two parts of flowers of sulphur, and expose the mixture in a glass vessel to a gentle heat, by means of the lamp-fur-



nace. As soon as the sulphur is heated to a little above its melting temperature, combustion suddenly pervades the whole mass, and the two bodies unite with an explosion—the result being the formation of sulphuret of copper. The most curious circumstance attending this experiment is, that it succeeds equally well if the vessel is closed so as to exclude air, or even if filled with nitrogen gas. Here, then, is an instance of combustion taking place, without the presence of either oxygen or chlorine. So that the theory which terms these bodies the supporters, and the only supporters, of combustion, is erroneous. The modern notion of combustion, that "it is the result of intense chemical action," appears to be the more correct one.

SULPHATE OF COPPER. BLUE VITRIOL.—It is a regularly crystallised salt, easily dissolved by water. The crystals are large and of a beautiful deep blue colour, and hence obtained the name of *blue vitriol.* They contain 36 per cent. of water of crystallisation. It is a salt that is of great use in several of the arts. It is caustic, reddens vegetable blues, and effloresces when exposed to the air. It is decomposed by heat, by pure and carbonated earths and alcalies, and by several metals. Obtained in the large way by roasting and washing sulphuret of copper. Produced when copper is boiled in oil of vitriol. Used in dyeing and colour-making.

This being a cheap salt, and one that readily forms fine crystals, is a good subject for young chemists to make their early attempts at crystallising upon.

NITRATE OF COPPER.—To make this salt, put a quarter of an ounce of shreds of copper into a test-glass, and pour over them half an ounce of nitric acid diluted with its bulk of water. An effervescence instantly commences, which is accompanied by a copious production of red nitrous acid gas. The liquor assumes a muddy greenish appearance; but afterwards becomes clear and of a beautiful blue colour, which is permanent; and a yellowish precipitate is found at the bottom of the vessel. To crystallise this salt, evaporate the saturated and filtered solution till a strong pellicle is formed on its surface, then set it by to cool. The crystallisation does not succeed well with a very small quantity of the solution. The crystals have the fine blue colour of the solution.

Nitrate of copper is very caustic and poisonous. Its crystals are deliquescent, soluble, and decomposable by heat. From the facility with which it parts with oxygen, this salt is capable of acting on several substances with much energy. Nitrate of copper is decomposed by the alcalies, by iron, and by several other bodies.

Chloride of Copper is of a beautiful deep green colour, and very acrid. It may be formed by corking up, in a small phial, some copper clippings, and a little muriatic acid: after a few weeks, a white powder will be seen at the bottom of the phial, and the liquid acid will have acquired the above-mentioned colour. The white powder is a basic salt of copper precipitated from solution. This green liquor gives a yellow chloride on evaporation, which heat reduces to a protochloride. The latter is converted by fusion into a brown crystalline mass, that turns green on exposure to air.

Arsenite of Copper.—A fine green substance, employed as a paint, known by the name of *Scheele's Green*. Made by adding a solution of arsenite of potash to a solution of sulphate of copper. This substance is used to imitate the colour of the turquoise on porcelain. *Mineral Green*, another very beautiful pigment, consists of arsenite and acetate of copper.

Acetate of Copper.—When plates of copper are exposed to the vapour of vinegar, a substance is formed, of a bluish-green colour, used in dying and painting, and called *verdigris*. This substance is a mixture of several basic salts; when dissolved in acetic acid, it forms neutral acetate of copper. This salt, is dark bluish-green; its crystals are soluble in five parts of hot water, but scarcely at all in cold. They are transparent, but effloresce on the surface in the air; they are decomposed by heat, yielding pure acetic acid. The chief use of this salt is in dyeing.

All the compounds of copper are violent poisons, and hence the danger arising from cooking food in untinned copper vessels, or rather of suffering it to remain in them after it is cooked. No fat or sour substance should be allowed to *cool* in a copper pot. The best antidote against the poison of copper is a substance always at hand—SUGAR.

URANIUM.

Uranium sometimes forms a cinnamon brown, dull powder; sometimes octahedral crystals of a dark grey colour, and metallic splendour. It dissolves in nitric acid, but not in muriatic or sulphuric acids. Its protoxide is used as a black colour in painting on porcelain. It is obtained from the mineral called *pitchblende.*

BISMUTH.

Metallic bismuth has a tin-white colour, verging towards reddish. This latter character serves to distinguish it from antimony, which it otherwise resembles in its leafy structure and its brittleness. It fuses more easily than lead, and can be volatilised in close vessels. When raised to a strong red heat in contact with the air, it burns with a pale blue flame. When heated on charcoal before the blowpipe, it throws upon the charcoal a yellow coating of oxide of bismuth. If fused in large quantity and cooled slowly, it crystallises in cubes.

Muriatic acid dissolves bismuth very sparingly. Nitric acid dissolves it easily, producing a solution of nitrate of bismuth. If pulverised bismuth is treated with fuming nitric acid, the mixture often becomes red hot. Sulphuric acid acts upon bismuth only when very strong and hot. Chlorine gas converts heated bismuth into chloride of bismuth.

Oxide of Bismuth.—A crust which forms when bismuth is melted in a crucible freely exposed to air. Yellow powder, fusible to a heavy yellow mass, easily reducible to the metallic state by fusion on charcoal before the blowpipe.

Sulphuret of Bismuth.—Precipitated as a black powder when sulphuretted hydrogen gas is passed into a solution o bismuth.

Nitrate of Bismuth.—The solution is colourless, but yields white crystals, which, on being put into water, suffer decomposition, and produce an insoluble sub-nitrate of a beautiful white colour, used as a paint, under the name of magistry of bismuth, and a soluble acid-nitrate. The white paint is readily blackened by sulphurous vapours.

Chloride of Bismuth.—Formed by heating two parts of corrosive sublimate, with one of bismuth, and expelling the superfluous substances by raising the heat. Grey, granular substance, easy of fusion, formerly called *butter of bismuth.*

Tartrate of Bismuth.—Obtained by precipitating a solution of nitrate of bismuth, by a solution of tartrate of potash. The precipitate is the cosmetic *pearl powder.*

TIN.

Tin is a yellowish white metal, possessed of great brilliancy, which it partially retains when exposed to air; soft, and very malleable. It can be beat into very thin leaves (*tin foil*), creaks when bent, so as to give a very peculiar sound, and exhales a very disagreeable odour when rubbed, especially if the fingers are moist. It melts nearly as readily as lead. Excluded from air, it does not easily volatilise. Heated in the air, it is converted into impure oxide of tin. At a white heat it burns with a blinding white light.

Nitric acid converts tin into insoluble peroxide of tin. Diluted and very cold nitric acid dissolves tin, and produces a solution of protonitrate of tin. Aqua regia and muriatic acid both dissolve tin, producing solutions of chloride of tin. Sulphuric acid dissolves tin, if concentrated, under disengagement of sulphurous acid gas; if dilute, under disengagement of hydrogen gas.

Protoxide of Tin.—Heavy black powder, which readily burns to peroxide of tin.

Peroxide of Tin.—The white substance, produced by putting metallic tin into nitric acid, is a hydrate of peroxide of tin. It dissolves both in acids and alcalies, acting either as a base or an acid. When ignited it loses water, turns yellow, and becomes insoluble in acids. Reducible to the metallic state by strong ignition on charcoal before the blowpipe. This oxide is used as an ingredient in *white enamels.*

Sulphuret of Tin.—A grey crystalline brittle mass, produced by heating tin and sulphur. Another sulphuret, containing more sulphur, and called *mosaic gold,* is made by exposing a mixture of equal parts of finely-powdered tin, sulphur, and sal ammoniac, to a heat rather below redness, and retaining it in that temperature for a considerable time. At a red heat the mosaic gold is decomposed. This substance is used in bronzing. It forms gold-coloured scales.

Chloride of Tin.—Tinfoil inflames spontaneously in chlorine gas, and produces chloride of tin. It is a thin, colourless, volatile, strongly-fuming liquid, which, in combination with one-third of its weight of water, produces a crystalline fusible mass. The *protochloride of tin* is a grey transparent fusible solid. With water it forms large transparent crystals—*tin salt,* used in dying.—*To make protochloride of tin,* dissolve pure tin in warm muriatic acid, evaporate the solution, and set it aside to crystallise. Dissolve the crystals in distilled water, and add a little muriatic acid to render the solution clear. You must prepare the solution every time you want it, as it will not keep good. It is sometimes used as a test.

LEAD.

Lead has a grey colour, and a strong metallic splendour. Its structure is not crystalline; it makes a black mark on paper; it is very soft; and when bent it makes no noise. It is heavier than silver; very easily fusible; volatilises at a white heat in close vessels, and at a red heat in the open air. It loses its metallic brilliancy in the air.

Muriatic acid does not dissolve lead. Nitric acid readily dissolves it, producing a solution of nitrate of lead. Concentrated and boiling sulphuric acid converts it into insoluble sulphate of lead. Chlorine gas passed over heated lead, changes it into chloride of lead.

Compounds of Lead :—

Lead.	Other Elements.	Oxygen.	Name and Weight of the Compounds.
52		4	56·0 yellow oxide of lead.
78		8	86·0 orange oxide of lead.
104		12	116·0 red oxide of lead.
26		4	30·0 brown oxide of lead.
26	9 chlorine.		35·0 chloride of lead.
26	4 sulphur.		30·0 sulphuret of lead.
26	4 sulphur.	8	38·0 sulphate of lead.
26	3·5 nitrogen.	12	41·5 nitrate of lead.

YELLOW OXIDE OF LEAD.—Yellow powder, which melts at a red heat into a yellow glass. Obtained by gently igniting the crystals of nitrate of lead. The *massicot* of commerce is identical with this oxide. *Litharge* contains this oxide, mixed with a little red lead.

RED OXIDE OF LEAD. *Common Red Lead.*—Lively red-coloured heavy powder, used as a paint. Heat converts it into yellow oxide and oxygen gas. Nitric acid produces nitrate of lead, and brown oxide of lead. Not easily prepared in small experiments.

BROWN OXIDE OF LEAD.—Dark brown powder, obtained by digesting red-lead in nitric acid. Inflames when triturated with sulphur. Becomes red-hot in sulphurous acid gas, and produces white sulphate of lead.

SULPHURET OF LEAD.—Occurs native, as *Galena*. Dark blue-grey, strong lustre, crystallises in cubes, and, when massive, readily splits into cubes. Formed by passing sulphuretted hydrogen gas into solutions of salts of lead. The sulphuret appears as a black precipitate.

SULPHATE OF LEAD.—White insoluble powder, produced when solutions of sulphates are added to solutions of lead-salts.

NITRATE OF LEAD.—Obtained by digesting lead in diluted nitric acid, sustaining the heat as long as effervescence continues; and, after filtration, evaporating the solution till a pellicle forms on its surface, when it is set aside to crystallise. Colourless octahedral crystals, free from water. Soluble.

CHLORIDE OF LEAD.—Formed when solutions of chlorides are added to solutions of lead salts. Small white crystals, very sparingly soluble in water.

IODIDE OF LEAD.—Prepared by adding a solution of iodide of potassium to a solution of acetate of lead. A yellow insoluble powder. If the solution is boiled, the iodide of lead forms most beautiful spangles, of the colour and lustre of burnished gold.

CHROMATE OF LEAD. CHROME YELLOW.—A fine yellow powder, used as a pigment. Prepared by adding chromate of potash to any solution of lead. A *subchromate*, possessing a beautiful cinnabar-red colour, is obtained by fusing the neutral chromate of lead with saltpetre.

CARBONATE OF LEAD, commonly known by the name of *white lead*, and much used as a white paint, is formed by exposing thin plates of lead, coiled up, to the vapour of vinegar. The metal is oxidised by the decomposition of the vapour of the acetic acid; and the salt is formed by the abstraction of carbonic acid, partly from the atmosphere, and partly from the acetic acid vapour. It can be formed in the small way, by adding a solution of carbonate of potash to a solution of nitrate or acetate of lead. It is a heavy white insoluble powder.

ACETATE OF LEAD.—Commonly called *Sugar of Lead*, in consequence of its sweet taste. Forms transparent needle-formed colourless silky crystals; very soluble in water; melts in its water of crystallisation. Its solution absorbs carbonic acid from the air, and appears muddy from the precipitation of carbonate of lead. It is much used in dyeing.

Subacetate of Lead, or Goulard's Extract, is prepared by boiling a mixture of two parts of acetate of lead, and one part of litharge, in water previously boiled, to expel carbonic acid.

TEST FOR LEAD.—Dissolve a grain of nitrate or acetate of lead in a glass of water, and add a little solution of sulphate of soda—a dense white precipitate (which is sulphate of lead) will be produced immediately; allow the mixture to settle, decant the clear part, and digest the precipitate in nitric acid; to the solution obtained by that means, add liquid sulphuretted hydrogen, upon which a precipitate of a black colour will be produced. Thus, in this experiment, the lead passes through the several states of an acetate, a sulphate, a nitrate, a sulphuret.

Remedy for the Poison of Lead.—The compounds of lead, especially those which are soluble, are poisonous, and produce a particular disease—the lead cholic, to which workmen are often liable. The best antidote to a dangerous dose of sugar of lead, is a solution of Epsom or Glauber's salts, swallowed in large quantity. Alum is also recommended as a good remedy.

CERIUM.

CERIUM forms a chocolate brown powder, to which friction communicates a feeble steel-grey splendour. It oxidises in moist air, and therefore always smells of hydrogen gas. It decomposes water. It inflames spontaneously when heated in the air, and detonates with chlorate and nitrate of potash.

COBALT.

Cobalt has a reddish-grey colour. It is somewhat malleable, very difficultly fusible, and remarkable for being attracted by the magnet, and for being able to retain the magnetic power.

Nitric acid dissolves cobalt very easily. The other acids dissolve it with more difficulty.

Oxide of Cobalt.—Greenish grey, easily reducible by hydrogen gas or charcoal. The soluble salts of cobalt are crimson-coloured; the insoluble salts mostly peach-blossom-coloured. The *peroxide of cobalt* is formed when the oxide or the soluble salts are strongly heated. It is black and insoluble in acids.

Nitrate of Cobalt.—Dissolve metallic cobalt, oxide of cobalt, or carbonate of cobalt, in nitric acid, and concentrate the solution by evaporation. It is a test for magnesia and alumina.

Chloride of Cobalt.—Obtained by dissolving cobalt in aqua regia. Pale red; gives a rose-red colour to its solution in water; forms, with water, garnet-red crystals. Its solution in water, acidulated with muriatic acid, forms the *blue sympathetic ink*. If muriate of soda is mixed with the cobalt in its preparation, the result is the *green sympathetic ink*.

Cobalt gives a deep blue colour to melted glass. Hence the use of this metal in colouring glass, enamel, and porcelain. It is also an ingredient in various pigments. —*Smalt*. Made by melting the roasted ore of cobalt with sand and potash, and pulverising the deep blue melted glass.—*Thenard's Blue*. This fine colour is made by adding a solution of alcali to a mixed solution of alum and cobalt salt, and igniting the precipitate.—*Rinmann's Green*. Made in the same way as Thenard's Blue, but substituting a salt of zinc for the alum.

NICKEL.

Nickel has a silver-white colour, and a strong metallic splendour. In the state of powder, as produced in certain experiments, it is greyish black. It is extremely hard, is malleable, and very difficult of fusion. It is attracted by the magnet, and can retain the magnetic influence. It oxidises when heated in the air; but a very high temperature reduces the oxide to the metallic state.

Nickel dissolves easily in nitric acid; it also dissolves in muriatic and sulphuric acids.

Oxide of Nickel.—Dark greenish grey. Easily reduced to the metallic state by ignition in presence of hydrogen or charcoal. The superoxide is black.

Nitrate of Nickel.—The solution has a splendid green colour. With solution of caustic potash, it gives an apple green precipitate. Ammonia colours it blue or violet, but gives no precipitate. Prepared by dissolving the metal or its oxide in nitric acid.

Nickel forms an ingredient in the *new silver* or *German silver*, which is an alloy of nickel, copper, and zinc.

IRON.

Iron has a light grey colour; but, when perfectly pure, it is nearly white. Combined with carbon, as in the state of crude and cast iron, its colour is more or less dark; yet steel has a lighter colour than bar iron, though it contains a greater proportion of carbon. Iron has a powerful metallic splendour, is very hard and malleable. Steel is harder than iron, especially after it has been heated, and then suddenly cooled. Cast iron is hard and brittle, especially when it is of a white colour; the grey-coloured cast iron is less brittle. All varieties of iron are attracted by the magnet, but steel retains the magnetic power longer than any other variety. This metal is distinguished, by its magnetic powers, from all others, excepting cobalt and nickel. Iron is extremely difficult of fusion; steel melts more easily than bar iron, and cast iron more easily than steel. Iron is not affected by dry air; but in moist air it is converted into *rust*, or hydrate of peroxide of iron. It is also oxidised when ignited in the open air or in oxygen gas. In the latter case, its combustion produces a brilliant light.

Iron is the most useful and most abundant of all the metals we are acquainted with. It is tenacious and ductile in a very eminent degree. It is malleable also, but less so than silver. One of its most advantageous properties is that of *welding*. By undergoing this process, peculiar to itself and platinum, two pieces of metal may be joined into one. The *loadstone*, in which the power of magnetism chiefly exists, is an iron ore. Iron is widely diffused: it is found in animals, vegetables, minerals, and meteoric stones.

Iron is capable of existing in solution in two different states. When it is dissolved in cold and dilute acids, and the solution is kept from the air, it is said to be present in the state of *protoxide*. When it is dissolved in hot and strong acids, it is said to form solutions of *peroxide*. These different sorts of solutions give different precipitates with the reagents. Pure solutions of protoxide are very difficult to prepare, as they attract oxygen from the atmosphere and become partially peroxidised with great facility. Pure solutions of peroxide can be always obtained by boiling any solution of iron for a few minutes with a small quantity of nitric acid.

Muriatic acid readily dissolves iron, disengaging hydrogen gas, and producing a solution of protochloride of iron. Diluted sulphuric acid readily dissolves iron, disengaging hydrogen gas, and producing a solution of protosulphate of iron. Cold nitric acid dissolves iron, and produces protonitrate of iron; while hot nitric acid produces pernitrate of iron. Chlorine gas passed over heated iron, produces volatile perchloride of iron.

Protoxide of Iron, an imaginary compound, supposed to be contained in the hydrate of protoxide of iron, in the protosalts of iron, &c.

Red Oxide of Iron.—Occurs native as iron glance and red iron-stone. Can be made by igniting green vitriol for an hour or two in a crucible; the heat must be strong. It forms a red powder — the colouring matter of common bricks and tiles. It dissolves but slowly in acids after ignition; is completely soluble, however, in boiling muriatic acid, with which it produces a solution of perchloride of iron.

Black Oxide of Iron.—Black scales produced by hammering iron when strongly heated. Its composition is the same as that of magnetic ironstone.

Sulphuret of Iron.—Iron combines with sulphur when heated, with a production of fire. A roll of sulphur bores a hole through bar-iron or steel at a white-heat, but not through cast-iron. Iron-filings, mixed with sulphur and moistened, gives, at common temperatures, a black pulverulent sulphuret. Iron produces sulphurets, the highest of which is the common mineral *iron pyrites*. This has a bright brass-yellow colour, and much splendour, is hard, not magnetic, and insoluble in diluted acids. Deprived by dry distillation of part of its sulphur, and thereby rendered equal in composition to another mineral, *magnetic pyrites*, or to a sulphuret produced by mixing and melting 2 parts of sulphur with 3 parts of iron-filings. Yellow, splendent, soluble in diluted acids, under disengagement of sulphuretted hydrogen gas; converted, by roasting in the open air, into green vitriol or protosulphate of iron.

To form Sulphuret of Iron.—Expose a bar of iron to a white heat in a furnace or smith's forge, and then touch the end of it with the end of a roll of sulphur, holding the two together so as to form the letter V. The sulphur must be held with a cloth, not with the naked hand. If the iron is not hot enough, it sets the sulphur on fire, and produces no sulphuret. A shower of sparks is produced, and the sulphuret, as it falls to the ground in the state of a thin liquid, divides into innumerable small globules, producing a beautiful appearance. If you want to collect the sulphuret, let it run down into water contained in an iron basin. You can cut a piece of iron in two, by means of a roll of sulphur applied in this way. Be careful not to let the hot sulphuret run upon your hands. It is easily avoided, by holding the iron and sulphur together in the V form.

Sulphate of Iron.—The body well known by the name of *green vitriol* and *copperas*. It forms beautiful transparent green crystals, which effloresce in dry air and turn yellow. Its taste is harsh and styptic. It reddens vegetable blues, the acid being always in excess. Two parts of cold and three-fourths of boiling water dissolve it. The pale green solution of sulphate of iron is acted on by the oxygen of the atmosphere. gradually depositing a yellow subsalt and acquiring a brownish colour, from the formation of peroxide. A moderate heat drives off its water of crystallisation, and a strong heat its acid. The water-free salt is white and opaque. Sulphate of iron is of extensive use in the arts of dyeing, ink-making, &c.

Sulphate of iron is very easily made, by dissolving iron in cold and diluted sulphuric acid (page 97). When evaporated and set aside, it readily forms very fine pale bluish-green crystals. It is a very good substance for beginners to make experiments upon.

CHLORIDES OF IRON. — I. *Protochloride.* White mass, fusible and volatile at a strong heat, sublimes in glancing spangles. Soluble in water. Produced by igniting iron in muriatic acid gas, or solution of iron in liquid muriatic acid. From the pale green solution, it crystallises with water in pale green deliquescent crystals. — II. *Perchloride.* Sublimes in tabular, semi-metallic glancing crystals; deliquescent; very easily soluble. Produced by gentle ignition of iron in chlorine gas, by solution of red oxide of iron in muriatic acid, or of metallic iron in aqua regia. The solution is yellowish-brown, very styptic, and partially decomposable by evaporation. The solution of perchloride of iron is a test to distinguish red prussiate of potash from yellow prussiate of potash in solution; it gives a blue precipitate with the yellow salt, but none with the red salt.

PHOSPHURET OF IRON.—Silver-white, susceptible of a fine polish, very hard, brittle. Produced by melting iron with bone ashes, sand, and charcoal.

CYANIDE OF IRON.—It is said that there is a protocyanide, a percyanide, and a compound of 3 particles of the former with 2 of the latter. This compound, in combination with water, forms pure *Prussian blue.* The Prussian blue of commerce contains a large proportion of alumina. A better substance than alumina for giving body to Prussian blue is precipitated carbonate of zinc.

CARBONATE OF IRON.—The substance which, in combination with an excess of carbonic acid, constitutes *chalybeate* mineral waters. *Preparation.*—To a solution of green sulphate of iron, add a solution of carbonate of soda. When the precipitate has settled, decant the solution; add fresh water, agitate the whole, and after the settling of the precipitate, again decant it. Repeat this till the water ceases to acquire sulphate of soda from the precipitate; then gather the latter on a linen filter, and squeeze it dry by the hand. This carbonate, added to a solution of carbonic acid in water, dissolves and produces an artificial chalybeate water. It is used in medicine.

Oxalate of Iron.—Yellow powder; difficultly soluble. When gently ignited, it yields carbonic acid gas, and finely-divided metallic iron, which is gifted with the property of spontaneous inflammation on exposure to the atmosphere.

Gallate of Iron.—Bluish-black, insoluble powder; the colouring matter of common writing-ink and black dyes. It is formed by adding gallic acid to solutions containing iron. It is decomposed by several other acids; hence ink-spots are taken from paper or linen by the application of oxalic acid, &c.

Acetate of Iron.—Used by dyers under the name of *iron liquor*. May be formed by precipitating a solution of sulphate of iron, by a solution of acetate of lead. Sulphate of lead falls down, and acetate of iron remains in solution.

CADMIUM.

Cadmium is a tin-white metal, brilliant, and soft; when bent, it creaks like tin. It is very easily fusible. Heated in the air, it burns and produces a brownish-yellow smoke of oxide of cadmium.

Nitric acid dissolves cadmium very easily, producing a solution which contains nitrate of cadmium.

Sulphuret of Cadmium is a fine orange-coloured substance, which might be used as a pigment if it could be procured in sufficient quantity.

ZINC.

Zinc is of a brilliant bluish-white colour, and a fibrous structure. It is flexible, and can be beat into leaves. It can be beat out best when rather hotter than boiling water. But when heated nearly to its melting point, and when very cold, it is brittle. It melts pretty readily, and at a white heat is volatile and can be distilled. When the metal is fused in the open air, it takes fire, continues to burn with a dazzling bluish-green flame, and is oxidised so rapidly that the oxide flies up in light white filaments, called flowers of zinc or philosophical wool.

Zinc readily dissolves in cold and diluted muriatic and sulphuric acids, under a rapid disengagement of hydrogen gas. It also dissolves in nitric acid.

To *granulate zinc*, or reduce it to small pieces, melt it in an iron ladle, and drop it into cold water.

COMPOUNDS OF ZINC.

Zinc.	Other Elements.	Oxygen.	Name and Weight of the Compounds.
16		4	20 Oxide of Zinc.
8	9 Chlorine.		17 Chloride of Zinc.
8	4 Sulphur.		12 Sulphuret of Zinc.
8	4 Sulphur.	8	20 Sulphate of Zinc.

OXIDE OF ZINC.—A white powder, which turns yellow whenever it is exposed to heat. Reducible by ignition with charcoal, but not by hydrogen gas. Prepared by precipitating sulphate of zinc by a caustic alcali.

SULPHURET OF ZINC.—Occurs native, and called blende. Cannot be prepared by art. The white precipitate produced by adding sulphuretted hydrogen to a solution of zinc, contains not only sulphur and zinc, but oxygen and hydrogen.

SULPHATE OF ZINC.—Produced by pouring sulphuric acid diluted with six parts of water upon granulated zinc. The metal is dissolved by the acid, forming a colourless solution, while hydrogen escapes in the gaseous state, see page 97. If the solution is rapidly evaporated to dryness, the salt is obtained in a mass which bears a resemblance to loaf-sugar. But, if slowly evaporated to the due degree of density, it shoots, on being allowed to cool, into regular crystals.

This is the *white vitriol* of commerce; the crystals are large, transparent, colourless, very easily soluble in water, and fusible by heat, under a loss of 44 per cent. of water of crystallisation. This salt is used in dyeing.

CHLORIDE OF ZINC.—Grey, transparent, soft, fusible, volatile, deliquescent. Prepared by the spontaneous inflammation of thin zinc foil in chlorine gas, or by solution of zinc in diluted muriatic acid.

Cyanide of Zinc.—White insoluble powder, used in medicine. Prepared by adding free Prussic acid to a solution of acetate of zinc.

Alloys of Zinc.—The *new silver*, or German silver, is formed by fusing together 5 parts of nickel, 5 of zinc, and 15 of copper. *Brass* is formed of zinc and copper.

MANGANESE.

Manganese is greyish white, and not possessed of much splendour. It is very brittle, and very difficult to melt. It becomes oxidised in the air, and falls to a black powder. It decomposes water, and disengages hydrogen gas. It readily dissolves in acids.

Protoxide of Manganese—Dark grey-green powder. Prepared by igniting carbonate of manganese in a gun barrel, and passing hydrogen gas over it. When heated in the open air, this oxide burns to brown oxide of manganese.

Red Oxide of Manganese.—Reddish brown powder, obtained by strong ignition of peroxide of manganese, or deutoxide of manganese; or by a less powerful ignition of carbonate or protoxide of manganese.

Deutoxide of Manganese.—Occurs as a mineral. Black. May be obtained by exposing peroxide of manganese to a long-continued low red heat.

Peroxide of Manganese.—An abundant mineral. Dark steel-grey, shining crystals or crystalline masses, employed in producing oxygen gas and chlorine gas, in glass-making, as a means of rendering it colourless when iron is present, and as a colouring matter in glass and porcelain painting. On exposure to a gentle ignition, it gives 9 per cent. of oxygen gas, and is converted into deutoxide; on exposure to a white heat, it yields 12 per cent. of oxygen gas, and produces brown oxide; on exposure to heat with sulphuric acid, it gives 18 per cent. of oxygen gas, and leaves a solution of sulphate of manganese.

Sulphate of Manganese.—Prepared as described in the preceding paragraph. The solution gives pale rose-red crystals when concentrated by evaporation. When mixed with a solution of potash it gives a precipitate of white hydrate, which, on being exposed to air, is quickly converted into a brown hydrate containing an increased quantity of oxygen.

Chloride of Manganese.—Rose red, fusible, deliquescent mass, soluble in water, with which it forms rose-red crystals. Obtained by boiling peroxide of manganese in muriatic acid, a process employed in preparing chlorine gas.

THORIUM.

Heavy grey powder. When heated, it burns to Thoria, a white powder resembling the earths in its properties.

ZIRCONIUM.

Zirconium forms a black powder, which friction renders dark iron-grey. It is infusible. If heated in the air it takes fire, gives out much light, and is converted into a white oxide termed zirconia.

Zirconium dissolves in hydrofluoric acid, but not readily in other acids.

Zirconia is a white infusible powder, which dissolves in sulphuric acid.

ALUMINUM.

Aluminum resembles pulverulent platinum, and acquires a perfect tin white metallic splendour by friction. It does not soften in the heat which liquifies cast iron. Heated in the air, it burns with a powerful light to alumina. In oxygen it burns with a light almost too powerful for the eyes to suffer. Aluminum dissolves readily in aqueous acids, and in solutions of fixed alcalies. It also dissolves in liquid ammonia, from which it disengages hydrogen gas.

Oxide of Aluminum, or Alumina, is an earth, which, as constituting the plastic principle of all clays and loams, was called *argil*, or the *argillaceous earth*, but now, as being obtained in greater purity from *alum*, is styled *alumina*. Pure *alumina* is soft, pulverulent, white; adheres to the tongue, forms with water a smooth paste, produces no change on vegetable colours, is insipid, inodorous, and insoluble in water, but mixes with it in all proportions. It is infusible, but hardened by fire. It is the basis of some hard gems, namely, sapphire, ruby, and corundum, in which it is the hardest of all bodies, next to the diamond. It is used in the manufacture of all kinds of *earthenware*.

Preparation of Alumina.—Precipitate a solution of crystallised alum with an excess of a solution of carbonate of potash; wash the precipitate, dissolve it in muriatic acid, and supersaturate the solution with ammonia; this produces an extremely bulky gelatinous precipitate of hydrate of alumina; wash, dry, and ignite it, whereby it shrinks together very much. The ignited substance is pure alumina, which in that state is difficultly soluble in acids, but readily soluble in solutions of caustic potash and soda.

Alumina is distinguished from other earths by its solubility in caustic potash; by giving octahedral crystals of alum when mixed with potash and sulphuric acid, and by acquiring a blue colour when moistened with a solution of nitrate of cobalt, and ignited on charcoal before the blowpipe.

SULPHATE OF ALUMINA.—Crystallises in thin, pearly, soluble spangles.

ALUM is a salt containing a certain quantity of *sulphate of alumina*, combined with a certain quantity of some other sulphate. Thus, sulphate of alumina and sulphate of potash make *potash alum*, (the common kind); sulphate of alumina and sulphate of soda make *soda alum*; and sulphate of alumina and sulphate of ammonia make *ammonia alum*. Besides which three kinds of alum, there are several others. Alum crystallises in regular octahedrons, transparent and colourless, its taste is astringent, its reactions somewhat acid; it contains $45\frac{1}{2}$ per cent. of water of crystallisation. It dissolves sparingly in cold water, abundantly in hot water. When heated, it intumesces strongly, gives off its water of crystallisation, and produces an inflated white pulverulent mass—*burnt alum*.

SILICATE OF ALUMINA.—This occurs abundantly in the mineral kingdom, and constitutes the principal ingredient of common clay, of porcelain, of stone-ware, and of all potter's-ware, tiles, bricks, &c., on account of which numerous uses, it may be considered as one of the most valuable of nature's mineral productions.

The *silicates of alumina* which occur in the mineral world, appear to me to belong to the silicates which I have described at page 110. The silicate of alumina I suppose to consist of *one particle each* of aluminum, silicium, and oxygen; and the aluminous minerals I suppose to consist of one or more atoms of this silicate, combined with one or more atoms of some other silicate. Thus:—

Cyanite is silicate of alumina, with silicic acid.
Feldspar is ditto, with silicate of potash.*
Albite is ditto, with silicate of soda.
Petalite is ditto, with silicate of lithia.
Harmotome is ditto, with silicate of barytes.
Emerald is ditto, with silicate of glucina.

YTTRIUM.

Yttrium forms an iron-black brilliant powder. If heated in the air, it burns to a white oxide, which is yttria. In oxygen gas it burns with a very brilliant light. It dissolves in diluted acids, under disengagement of hydrogen gas.

Oxide of Yttrium or Yttria has a dirty yellow colour after ignition. Its hydrate is white, tasteless, inodorous, infusible, heavy, and insoluble. It dissolves in acids, but not in caustic potash. It is obtained from the mineral *Gadolinite.* With borax it melts into a glass.

GLUCINUM.

Glucinum forms a dark grey powder. If ignited in the open air, it inflames and burns with much vigour; its combustion in oxygen gas is attended by a light of extraordinary splendour. The product of the combustion is glucina. Glucinum dissolves in acids and in a solution of potash, but not in ammonia. The salts of glucina have a sweet but astringent taste.

---

* "Feldspar is so constituted, that if we suppose the silicium to be exchanged for sulphur, alum would be produced." Wöhler, *Grundriss der Chemie*, 1833, p. 130. This assertion runs through most chemical books. I do not think it correct. The silicates appear to me to differ from the sulphates, not only in containing silicium instead of sulphur, but in containing only half as much oxygen.

Glucina.—A white tasteless powder, insoluble in water, but soluble in acids and in caustic alcalies. It is obtained from the *emerald* and the *beryl*.

MAGNESIUM.

Magnesium is silver white, possessed of a strong metallic splendour, hard and malleable; about as fusible as silver; not affected by dry air; burns when heated in the air or in oxygen gas with a most brilliant light, and produces magnesia. It dissolves in acids, and produces solutions containing salts of magnesia, all of which are characterised by a peculiar bitter taste, well known as the taste of Epsom salts.

Magnesia.—A fine white light powder, tasteless and inodorous, infusible in common fires, almost insoluble in water. If laid on reddened litmus paper and moistened, it changes the colour to blue. Produces no heat when mixed with water. *Preparation.*—Add a solution of carbonate of potash to a boiling solution of sulphate of magnesia. The precipitate is to be washed, filtered, dried, and ignited. The residue is pure magnesia, the *calcined magnesia* of commerce.

Sulphate of Magnesia.—To form this, saturate the common magnesia of the shops with diluted sulphuric acid, filter the solution, and crystallise the salt by concentrating the solution, and then allowing it to cool. For the purposes of experiment, dissolve, filter, and recrystallise the sulphate of magnesia (Epsom salts) of the shops.

Sulphate of Magnesia obtained the name of *Epsom salts* from having been obtained, for a long time, by evaporating the water of the saline springs at Epsom, in England. It is now generally obtained from sea water, in which it exists in large quantities, mixed with chloride of sodium. Its taste is cool, bitter, and saline. It is very soluble, requiring only an equal weight of cold water, and three-fourths its weight of hot. It effloresces in the air, though but slowly. When heated, it dissolves in its water of crystallisation, which amounts to 51 per cent. of its weight, but is not decomposed. It is chiefly used as a purgative in medicine, and to furnish magnesia by its decomposition.

Carbonate of Magnesia.—Prepared by adding a solution of carbonate of potash to a boiling solution of sulphate of magnesia. The washed and dried (but not ignited) precipitate forms a white, tender, light mass, commonly called *magnesia*, or *magnesia alba*. This powder is a mixture or compound of carbonate of magnesia, with hydrate of magnesia. To obtain pure carbonate of magnesia, it is necessary to expose magnesia mixed with water to a current of carbonic acid gas. It forms transparent crystals, which contain 27 per cent. of water of crystallisation.

Test for the purity of Magnesia.—The common magnesia of the shops is frequently adulterated with chalk; this may be detected by adding a little diluted sulphuric acid, which, with magnesia, forms a very soluble salt, but with lime, an insoluble one. Pure magnesia (called *calcined* magnesia in the shops) dissolves in diluted sulphuric acid entirely, and without effervescence.

AMMONIUM.

Ammonium is not a simple substance, but a compound metal composed of four volumes of hydrogen gas in combination with one volume of nitrogen gas. Its existence is suppositional, for it has never been produced in a separate state. But there exists a series of compounds, called *salts of ammonia*, which bear a striking resemblance to another series of compounds called *salts of potash*. And if you examine the salts of potash and of ammonia, pair by pair, you will find them to agree precisely in composition, excepting that, where in the potash salt you have 10 parts by weight of metallic potassium, you have in the ammonia salt 4·5 parts by weight of a compound of hydrogen and nitrogen, combined invariably in the proportion of 1 in weight (4 in bulk) of hydrogen, and 3·5 in weight (1 in bulk) of nitrogen. Hence, in all these compounds, the metal potassium is replaced by what we may term the imaginary metal ammonium.

The following table of the constitution of these compounds places the subject in a striking point of view.

Potassium.	Ammonium.	Oxygen.	Other Elements.	Name and Weight of the Products.
10		4	0·25 Hydrogen.	14·25 Caustic Potash.
	4·5	4	0·25 Hydrogen.	8·75 Ammonia in water.
10			4· Sulphur.	14· Sulphuret of potassium.
	4·5		4· Sulphur.	8·5 Hydrosulphuret of amm.
10		8	4· Sulphur.	22· Sulphate of potash.
	4·5	8	4· Sulphur.	16·5 Sulphate of ammonia.
10		12	3·5 Nitrogen.	25·5 Nitrate of potash.
	4·5	12	3·5 Nitrogen.	20· Nitrate of ammonia.
10			9· Chlorine.	19· Chloride of potassium.
	4·5		9· Chlorine.	13·5 Muriate of ammonia.
10		8	3· Carbon.	21· Oxalate of potash.
	4·5	8	3· Carbon.	15·5 Oxalate of ammonia.
20		12	3· Carbon.	35· Carbonate of potash.
	9·0	12	3· Carbon.	24· Carbonate of ammonia

And thus it is with all the compounds which contain potassium and ammonium. They agree not only in constitution but in many properties, and the same thing holds even with the double salts. Thus, the double chloride of platinum and potassium is matched precisely by the double chloride of platinum and ammonium; these two salts are alike in most of their properties: they possess the same colour, are formed in the same manner, dissolve in the same liquids, crystallise in the same form; and contain the same quantity of platinum and the same quantity of chlorine; they differ in one circumstance only, which is that where the one salt contains 10 parts of potassium, the other contains 4·5 parts of ammonium.

Farther, potassium forms an amalgam with mercury, and so also does ammonium; but though potassium can be separated from the amalgam of potassium, ammonium cannot be separated from the other amalgam. We know nothing more of ammonium than that it acts the part of a metal in compound bodies, and that its constituents are nitrogen and hydrogen.

SULPHURET OF AMMONIUM.—Produced by the combination of two volumes of ammoniacal gas with one volume of sulphuretted hydrogen gas. Colourless, exceedingly volatile, powerful and disagreeably-smelling needle-formed crystals. In the liquid state, known as *Hydrosulphuret of Ammonia.* Prepared by passing a current of sulphuretted hydrogen gas into liquid ammonia, until the solution is saturated with the gas. The bottle which contains the liquid ammonia should have a very narrow mouth, because the contact of atmospheric air is to be avoided as much as possible. It is a colourless liquid, which smells strongly both of sulphuretted hydrogen and ammonia, much used in analytical chemistry to precipitate metals from solutions in the state of sulphurets.

SULPHATE OF AMMONIA.—Take dilute sulphuric acid in a glass; throw a lump of carbonate of ammonia into it. The solid swims up and down in the liquid, disengaging many bubbles of gas. The gas thus produced is carbonic acid. The resulting solution holds sulphate of ammonia. If strong sulphuric acid is poured upon strong liquid ammonia, a violent action is produced. A great heat is excited, and dense fumes thrown off. Sulphate of ammonia forms colourless crystals, easily soluble in water, not alterable by air. Decomposed and sublimed by heat.

NITRATE OF AMMONIA—*Inflammable Nitre.*—It is obtained in crystals, which differ in their appearance, according to the degree of heat employed to evaporate the water of solution. The taste is extremely cold and acrid. It dissolves in 2 parts of cold water, and in half its weight of boiling water. It deliquesces. The most remarkable property of this salt is, that, when thrown on a red hot iron, it explodes with a loud noise, accompanied by a white flame. The chief use of nitrate of ammonia, is for affording nitrous oxide gas, by a certain mode of decomposition.

NITRATE OF AMMONIA.—Formed as follows: Saturate nitric acid diluted with five parts of water, with carbonate of ammonia. Filter the solution. Then evaporate by a gentle heat, and, to supply the waste of the alcali, which is volatilised by the heat, add, occasionally, a little more of the carbonate. When the evaporation has proceeded to a certain extent, the solution is set aside, and the salt crystallises.

Chloride of Ammonium,—Muriate of Ammonia,—Hydrochlorate of Ammonia,—Sal Ammoniac.—This is the most important of the salts of ammonium. It is obtained by combining two volumes of ammoniac gas with one volume of chlorine gas, by saturating liquid ammonia by muriatic acid, or by dissolving carbonate of ammonia in muriatic acid. In the large way it is prepared by the dry distillation of animal matter, such as horn, bones, &c., which produces a solution containing carbonate of ammonia. This is either saturated direct with muriatic acid, or first with sulphuric acid, and the resulting sulphate of ammonia is afterwards distilled with chloride of sodium, upon which chloride of ammonium sublimes. This commercial sal ammoniac appears in the form of round semitransparent tough cakes of fibrous crystalline texture. It has a sharp saline cooling taste, is easily soluble in water, and crystallises thence in octahedrons and cubes. When heated, it sublimes without undergoing decomposition. The white smoke in which it sublimes has a very peculiar smell. Great cold is produced, both by its solution in water, and its mixture with pounded ice: hence, it is useful here for frigorific mixtures, and, in warm countries, for cooling wines. Few salts are of more extensive use than this. In chemistry, medicine, metallurgy, dyeing, and many other arts, it is much employed; and it is indispensable in operations whereby the surfaces of some metals are coated with others—for example, in the tinning of copper.

Phosphate of Ammonia.—Large clear crystals, formed by saturating phosphoric acid with ammonia.

Carbonate of Ammonia.—Obtained by subliming a mixture of 1 part of sal-ammoniac and 2 parts of chalk. White, very volatile, having the smell of ammonia, crystallisable. Vulgarly called *smelling salts*. It is soluble in rather more than twice its weight of cold water; and in its own weight of hot water; but a boiling heat volatilizes it. It is not decomposed by heat, though so readily sublimed. It is soluble in the atmosphere: if left in a state of exposure, it diffuses its smell, and diminishes in weight.

Carbonate of ammonia is employed as a chemical test. Buy it in the solid state, dissolve it in distilled water and filter the solution. The bottle must have a stopper that fits well, and should be kept in a cool place. It is a test for many earths and metals.

Oxalate of Ammonia.—Colourless, transparent crystals, difficultly soluble in water. Employed in chemical analysis to precipitate lime, from solutions of which it throws down oxalate of lime, the most insoluble of all the salts of lime. Oxalate of ammonia is prepared by adding carbonate of ammonia to a solution of oxalic acid till it is neutralised. The solution is filtered, evaporated, and set aside to crystallise.

CALCIUM.

Calcium is silver-white and solid. It rapidly becomes oxidised in the air. When heated in the air, it burns brilliantly, and produces dry lime. It decomposes water, discharging hydrogen gas, and producing a solution of lime.

The following table exhibits the composition of some important compounds of calcium.

Calcium.	Oxyg.	Other Elements.		Names and weights of the products.	
10	4			14·	Lime
5	4	0·25	Hydrogen	9·25	Hydrate of Lime
5		9·	Chlorine	14·	Chloride of Calcium
5	8	4·	Sulphur	17·	Sulphate of Lime
5	8	3·	Carbon	16·	Oxalate of Lime
10	12	3·	Carbon	25·	Carbonate of Lime
5	12	3·5	Nitrogen	20·5	Nitrate of Lime

Lime.—The most important and the widest spread of all the earths. As carbonate and sulphate, it forms whole mountains. As phosphate, it constitutes the bones of animals.

Lime is a soft white substance, with a caustic, astringent, and alcaline taste. It fuses with great difficulty. It is slightly soluble in water. One part of lime requires about 500 parts of water to dissolve it. It renders vegetable blues, green; and yellows, brown; and restores to reddened litmus, its usual purple. If a little water only be sprinkled upon dry newly-burnt lime, it is rapidly absorbed, with the evolution of much heat and vapour. It has a strong tendency to combine with carbonic acid, which it rapidly absorbs when exposed to the atmosphere.

Pure Lime is obtained by exposing oyster-shells, marble, or chalk, to the action of a clear kitchen fire, for about an hour, the heat drives off carbonic acid, and the substance remaining, is pure lime, which must be put into a bottle while warm, and be well secured from the air.

Sulphuret of Calcium.—Obtained (*a*) by igniting sulphate of lime with charcoal; (*b*) by igniting lime in sulphuretted hydrogen gas; (*c*) by igniting lime with sulphur.—Yellowish earthy infusible hepatic mass, very slightly soluble. Phosphorescent, i. e. after exposure to the sunshine it gives light in darkness.

Sulphate of Lime.—Large mountains are formed of this salt, which in various states has received the names of gypsum, plaster of Paris, alabaster, anhydrite, &c. Crystallised gypsum and alabaster contain 27 per cent. of water. By calcination, gypsum is deprived of its water, and converted into stucco or plaster of Paris, a fine white powder. When this is mixed with water, heat is produced, and the mixture hardens to a solid mass, slightly enlarging its bulk. Hence the use of stucco in making images, medallions, and other ornamental articles. Sulphate of lime dissolves in about 460 parts of water, and crystallises from its solution in small needles. These needles are produced when sulphuric acid is added to any solution of lime.

Nitrate of Lime.—To form this, nitric acid, diluted with five or six parts of water, must be saturated with carbonate of lime. When the solution is boiled down to the consistence of a syrup, and exposed in a cool place, the salt crystallises. Its crystals resemble bundles of needles, diverging from a centre. Its taste is hot and bitter. It deliquesces in the air, and is so extremely soluble, that it can only be kept in the dry state with great difficulty. It is soluble in an equal weight of alcohol.

Chloride of Calcium.—Obtained by dissolving marble in muriatic acid, evaporation, and fusion. It is a product of the preparation of ammonia. A white crystalline fusible substance, of bitter, saline, disagreeable taste; it rapidly absorbs water from the atmosphere, and deliquesces, on which account it is used to dry gases, and to abstract water from alcohol. Dissolves with heat in water, and crystallises from its concentrated solutions in extremely large transparent columnar crystals, which contain 49 per cent. of water. The crystals dissolve in half their weight of cold water, under production of a very great degree of cold, on which account they are employed in freezing mixtures.

Chloride of Lime.—*Tennant's Bleaching Powder.*—Prepared in the large way by saturating hydrate of lime with chlorine gas. I consider it a compound of chloride of calcium with peroxide of hydrogen. A solution resembling the solution of chloride of lime in water, can be prepared by passing chlorine gas into milk of lime. It smells of chlorine, and discharges chlorine when mixed with acids. It is employed in bleaching cotton and linen, and in destroying bad smells and the effluvia of sick-rooms.

Fluoride of Calcium.—Occurs native as *Fluor Spar*, in cubic and octahedral crystals, sometimes colourless, sometimes tinged with shades of green, purple, rose, yellow, and innumerable other colours. The fluoride of calcium prepared by art is an insoluble white powder. The fluor spar found in Derbyshire is a very beautiful variety, and is much employed in the formation of various ornaments for cabinets, and of cups, candlesticks, &c. It is insoluble. When heated, it decrepitates, loses its water of crystallisation, and afterwards shines in the dark. At a strong heat, it melts into a glass. Several acids, when assisted by heat, decompose fluoride of calcium, and expel hydro-fluoric acid in white fumes. Fluor spar is the material from which all the fluorides are prepared.

Phosphuret of Calcium.—Prepared by igniting lime in a tube, and making phosphorus sublime over it, or by putting bits of phosphorus into a glass flask containing ignited lime. A reddish-brown mass containing phosphate of lime, and commonly called phosphuret of lime. This substance, when thrown into water, disengages spontaneously inflammable phosphuretted hydrogen gas.

Phosphate of Lime.—This is the basis of the bones of animals, and the principle which gives to them their hardness and strength: hence it is a body of great importance. It is not only found in bones, however, but in considerable abundance in a native mineral state, and it may be formed artificially. It is sometimes obtained crystallised, but generally in the form of a white powder, which is insoluble in water. By a violent heat, it may be fused into an enamel. It is used for making cupels, which are vessels employed by silversmiths in the operation of refining silver. It is also used in polishing gems and metals, to absorb grease from linen, paper, and silk, and as a medicine. It is identical with the burnt hartshorn of the shops.

Carbonate of Lime forms a considerable part of the solid strata of the globe. It is sometimes obtained pure; but generally mixed with other earths, with metals, coal, &c. It is occasionally obtained in transparent crystals. In these various states it is known by the names of *chalk, marble, limestone, stalactites, calc spar*, &c. With the exception of chloride of sodium, it is of more importance than any other of the salts. Carbonate of lime has no taste, is insoluble in water, but slightly soluble (like the other carbonates) in water impregnated with carbonic acid. But, by exposure to the air, the extra dose of carbonic acid flies off, and the salt reverts to its state of insolubility. It dissolves in acids with effervescence, giving off carbonic acid gas. No alteration is effected in it, on exposure to the air. When heated, it decrepitates, its water flies off, and lastly its acid; but this requires a pretty strong heat. By this process it is burned into lime. The specific gravity of this body is about 2·7, but varies according to its state of aggregation: chalk and marble are essentially the same in constitution, but very different in their relative weights.

To form Carbonate of Lime.—Mix lime water with water impregnated with carbonic acid gas. These liquids are individually transparent, but the mixture is opaque: a white powder gradually sinks to the bottom of the vessel, and proves on examination to be identical in composition with chalk and marble.

Oxalate of Lime.—White powder, perfectly insoluble in water. The oxalic acid precipitates lime from the solution of every calcareous salt, and serves to detect and separate calcium from all its combinations. By ignition in a platinum crucible over a spirit lamp, it is converted into carbonate of lime, under disengagement of carbonic oxide gas.

Hydrate of Lime.—Burnt lime, moistened with water, becomes extremely hot, swells up and produces a bulky dry white powder. This is *slaked lime* or *hydrate of lime*, in the formation of which 1 atom of oxide of calcium and 1 atom of water, by mutual decomposition and recombination produce 2 atoms of hydrate of lime. See page 95. 3 Parts of lime produce 4 parts of hydrate, which a weak red-heat can again reduce to 3 parts of lime. When an additional proportion of water is added to slaked lime, it forms a white paste, and with still more the white liquor called *milk of lime.* If this is allowed to settle, the undissolved hydrate falls to the bottom, and *lime water* in a transparent state remains above. This solution has alcaline powers, and is employed as a test. It absorbs carbonic acid freely from the atmosphere, and exhibits a skin of carbonate of lime. 500 Parts of water dissolve only 1 part of lime.

Burnt and slaked lime has the property of hardening with sand and water into a stony mass, termed *mortar.*

Tartrate of Lime.—Preparation:—Mix a solution of chloride of calcium with a solution of supertartrate of potash; filter the solution, and wash the precipitated tartrate of lime with the edulcorator (p. 32.). It is a test for arsenic. A very sparingly soluble, white, crystalline powder.

Acetate of Lime.—Soluble; crystallisable.

STRONTIUM.

Strontium nearly resembles barium.

Compounds of Strontium.—

Strontium.	Oxyg.	Other Elements.	Name and weight of the products.
22	4		26· Strontian
11	4	0·25 Hydrogen	15·25 Hydrate of strontian
11		9· Chlorine	20· Chloride of strontian
11	8	4· Sulphur	23· Sulphate of strontian
11	8	3· Carbon	22· Oxalate of strontian
22	12	3· Carbon	37· Carbonate of strontian
11	12	3·5 Nitrogen	26·5 Nitrate of strontian

Strontian has a considerable resemblance to *barytes* in its properties. It differs from it chiefly in being infusible, much less soluble, of a different form when crystallised, weaker in its reactions, and not poisonous. A peculiar characteristic of strontian is the giving of a blood-red colour to flame.

Sulphate of Strontian bears considerable resemblance to sulphate of barytes. It occurs native, in great abundance, in various parts of the world, usually in a crystallised form. It is insoluble in water, but not so completely insoluble as sulphate of barytes, for which reason a solution of sulphate of strontian can be employed as a test to distinguish a solution containing barium from one containing strontium, as it gives a precipitate with the former but not with the latter. To prepare this test, add an excess of sulphuric acid to a solution of nitrate of strontian or of chloride of strontian ; filter the solution, and wash the precipitate until the washings do not change the colour of litmus. Boil the edulcorated precipitate in distilled water, allow it to cool, filter the solution and preserve it.

Nitrate of Strontian.—A soluble crystallisable salt, which can be decomposed by heat. Applied to the wick of a candle, or added to burning alcohol, it gives a deep red, or purple colour to the flame. This is the characteristic property of strontian.

Chloride of Strontium.—Forms deliquescent crystals, soluble in less than their own weight of water. Taste cold and sharp.

Carbonate of Strontian is found native, but, as well as the preceding salts, may be formed artificially. The native substance appears in semi-transparent crystals, of a white colour tinged with green. It is insipid; insoluble ; not altered by exposure to the air ; but decomposed by heat. If thrown in powder on well kindled coals, it exhibits red sparks. It is much lighter than carbonate of barytes, (with which body it was long thought identical,) and is not poisonous.

BARIUM.

Barium resembles silver: it is easily fusible, and heavier than concentrated sulphuric acid. It becomes oxidised in the air, and burns with a red light when heated. It decomposes water and produces a solution of barytes.

Compounds of Barium :—

Barium.	Oxyg.	Other Elements.	Name and weight of the products.
35·	4		39· Barytes
17·5	4		21·5 Peroxide of barium
17·5	4	0·25 Hydrogen	21·75 Hydrate of barytes
17·5		9· Chlorine	26·5 Chloride of barium
17·5		4· Sulphur	21·5 Sulphuret of barium
17·5	8	4· Sulphur	29·5 Sulphate of barytes
17·5	8	3· Carbon	28·5 Oxalate of barytes
35·	12	3· Carbon	50· Carbonate of barytes
17·5	12	3·5 Nitrogen	33· Nitrate of barytes

Composition of *one part* of sulphate of barytes :—

Barium	0·593220
Sulphur	0·135594
Oxygen	0·271186
Sulphur and oxygen	0·406780

Barytes.—A greyish-white, earthy substance, of corrosive alcaline taste and alcaline reaction. Infusible in common fires. Its specific gravity is 4·0. It is a violent poison. It has no smell. When water is poured upon dry *barytes*, it slakes like quicklime, evolving, however, more heat. The hydrate is slightly soluble in water. It tinges the flame of burning alcohol yellow, the flame of the blowpipe green. Under the name of *permanent white*, it is used as a paint. It is employed by the chemist as a reagent. It is procured by exposing crystallised nitrate of barytes to a red heat in a porcelain crucible, keeping up the heat for an hour or two.

Peroxide of Barium.—Formed by heating barytes in oxygen gas. It dissolves in diluted acids without disengaging oxygen gas, and is used to prepare peroxide of hydrogen.

Sulphuret of Barium.—Formed when 8 parts of finely pulverised sulphate of barytes are mixed with 1 part of charcoal powder and 2 parts of rosin, and strongly ignited for an hour in a covered crucible. The sulphuret of barium can be dissolved out of the ignited mass, by being boiled in water. The filtered solution is transparent and colourless.

Sulphate of Barytes.—This salt may be easily, though it is seldom, formed by art; because it abounds in nature, especially in veins of metals. It is generally obtained in crystals, differently shaped. It is the heaviest of all the earthy salts, and is perfectly insoluble in water and in acids. It is tasteless and inodorous. It is *not poisonous,*—this property distinguishes *the sulphate* from all the other salts of this earth, which *are* poisonous. When formed into a thin cake with flour and water, and exposed for some time to a very strong heat, it shines afterwards in the dark. This property was discovered in Bologna, and hence the mineral has been termed *Bolognian phosphorus.* Sulphate of barytes is precipitated whenever solutions of sulphates come into contact with solutions of any compound of barium. It is a white powder.

Nitrate of Barytes.—Octahedral crystals which contain no water of crystallisation. Soluble in water. Poisonous. Decrepitates when heated. To procure this salt, add nitric acid to a solution of sulphuret of barium till effervescence ceases, and the solution reddens blue litmus paper. Sulphuretted hydrogen is disengaged and sulphur precipitated. Separate the latter by filtration, and evaporate the filtered solution till a pellicle appears on its surface. It may then be set aside, and on cooling will deposite nitrate of barytes in crystals.

Chloride of Barium.—Prepared in the same manner as nitrate of barytes, employing muriatic acid instead of nitric acid. A white mass which melts in a strong heat. It produces tabular crystals containing water of crystallisation, which decrepitate when heated and afterwards melt. It is soluble in water and in alcohol. It is not altered by air, and only partially decomposed by heat. It has a nauseous burning taste, and is poisonous; but is sometimes given medicinally in small doses. Like nitrate of barytes it is of great use as a *test* for sulphuric acid.

Carbonate of Barytes.—This is found native as Witherite, but not so abundantly as the sulphate of barytes. It crystallises, is very heavy, tasteless, inodorous, and nearly insoluble in water. It is not altered by air, but is decomposed by heat. It can be employed to produce nitrate of barytes or chloride of barium, instead of the solution of sulphuret of barium. The artificial carbonate of barytes is a white insoluble powder. To obtain it in a state of purity, add a solution of carbonate of ammonia to a solution of crystallised pure nitrate of barytes. Wash the precipitate till the water gives no precipitate with sulphuric acid. Then dry and expose it to a red heat in a platinum crucible.

Hydrate of Barytes.—Pure barytes, on being moistened with water, produces a very high degree of heat, absorbs the water and falls to a white pulverulent hydrate. This melts at a red heat, without losing any water. It is poisonous, dissolves largely in boiling water, and on cooling produces crystals, in which the hydrate is combined with water of crystallisation. It dissolves in 29 parts of cold water, producing *barytic water*, a solution which tastes and acts like an alcali, and absorbs carbonic acid on exposure to the atmosphere.

The barytic water is more effectual than lime water in denoting carbonic acid, and is more portable and convenient; since, from the pure earth, the solution may be at any time readily prepared. The barytic solution is also a most sensible test for sulphuric acid, which it indicates by an insoluble precipitate.

LITHIUM.

Lithium is said to be very similar to sodium. Hydrate of lithia is very similar to caustic potash, but not deliquescent and is sparingly soluble in water. It corrodes platinum at a red heat. The salts of lithium are unimportant.

SODIUM.

Sodium has a silver-white colour and strong metallic splendour. At a temperature below the freezing point of water, it is brittle; as the temperature rises, it becomes malleable, then wax-like, soon afterwards fluid, and at a red heat gaseous. It is lighter than water. It becomes slowly oxidised on exposure to dry air. It inflames when heated in the air. It decomposes water when thrown upon its surface; the metal whirls about, hissing, and disengaging hydrogen gas; occasionally it exhibits a yellow flame, especially when it first touches the water, and when it strikes against the sides of the vessel in which the water is held; and finally disappears, and yields a solution of soda.

It burns on hot water with a bright yellow flame. If thrown upon mercury it causes an explosion.

Compounds of Sodium :—

Sodium.	Oxygen.	Other Elements.		Name and Weight of the Products.	
12	4			16·	Protoxide of sodium, or soda
24	12			36·	Peroxide of sodium
6	4	0·25	Hydrogen	10·25	Caustic soda
6		9·	Chlorine	15·	Chloride of sodium
6	8	4·	Sulphur	18·	Sulphate of soda
12	12	3·	Carbon	27·	Carbonate of soda
6	12	3·5	Nitrogen	21·5	Nitrate of soda

PROTOXIDE OF SODIUM, ANHYDROUS SODA.—Obtained by burning metallic sodium in dry oxygen gas. Scarcely known.

SULPHURET OF SODIUM.—Sodium and sulphur, when heated together in a glass tube, combine, under disengagement of much heat and light, and produce sulphuret of sodium. By strongly igniting a mixture of charcoal and sulphate of soda, we obtain an impure sulphuret of sodium, contaminated by soda. It is a flesh-red, semitransparent, volatile, and soluble mass. A solution of sulphuret of sodium for test-liquor is obtained by boiling sulphur in a solution of caustic soda. It is a greenish-yellow liquid.

SULPHATE OF SODA is formed by adding sulphuric acid to a solution of subcarbonate of soda, till effervescence ceases. It is obtained in the large way by adding oil of vitriol to common salt. The solution must be filtered and evaporated for a short time, and then set by to cool, when crystals will be deposited. The remaining solution must be again evaporated, and again cooled, and this must be repeated till all the water is driven off. *Note.*—If you put a ready-formed crystal of the salt into the solution which you set by to cool, crystallisation will take place very speedily. The crystals are commonly known by the name of *Glauber's Salt.* They contain 55 per cent. of water of crystallisation, viz., 5 particles of water to 1 particle of salt. It is found native in various saline springs, and sometimes efflorescent on the walls of old houses. The taste of this salt is cooling and bitter. Its crystals, when in contact with the atmosphere, lose their water of crystallisation, and become pulverulent. It is soluble in three parts of cold water, and less than its own weight of boiling water; a saturated hot solution, when cooled, readily shoots into beautiful crystals. The crystals, on exposure to fire, liquify in a short time; and when an intense heat is applied to the dried salt, it undergoes the igneous fusion. It is used in medicine as a purgative. It is also employed in the manufacture of *carbonate of soda* and of *glass.*

NITRATE OF SODA.—Forms rhomboidal crystals. Behaves much like nitrate of potash. Is used to give a yellow colour to the flame of fireworks.

CHLORIDE OF SODIUM. KITCHEN SALT. SEA SALT. MURIATE OF SODA.—This abounds in the waters of the ocean, and chiefly occasions their peculiar taste. It is likewise found, in great abundance, in various parts of the globe, in a dry state. At Northwich, in England, is a salt mine, which yields 4000 tons of rock-salt a-year; and, in Spain, there is a remarkable solid mountain of salt, 500 feet high, and a league in circuit; its depth below the surface of the earth is unknown. This mountain is composed of salt, in a state of perfect purity. In short, salt is one of the most abundant bodies in nature, and one of the most useful. Its crystals form regular cubes, which commonly hang together in a pyramidal form. Its pure saline taste is well known. It dissolves in about 2½ parts of water, more readily in cold than in hot water. It is not affected by exposure to the atmosphere. When heated, it breaks with a loud crackling noise, which phenomenon is termed *decrepitation.* By a greater heat it may be fused, and by a still greater volatilised; but it is not decomposed by heat.

Chloride of sodium may be formed by dropping muriatic acid into a saturated solution of subcarbonate of soda, as long as effervescence takes place. The solution is then to be filtered, and the salt crystallised by evaporation.

To purify common chloride of sodium, for chemical purposes, dissolve it in boiled water; filter the solution; and add a solution of carbonate of soda as long as any milkiness ensues. Filter the solution, and evaporate till crystallisation.

Bromide, Iodide, and Fluoride of Sodium, all crystallise in cubes, and much resemble the chloride.

Phosphate of Soda.—Forms large transparent crystals. Its taste is very similar to that of common salt. Its crystals are soluble in two parts of boiling water, or four of cold water; they effloresce superficially in the air, and when heated, undergo the watery fusion. At a red heat they melt into a white enamel, and before the blowpipe into a transparent globule, which, on cooling, becomes opaque. It is much used by mineralogists in the fusion of minerals.

Ignition gives new properties to the phosphate of soda, a fact first noticed by Dr Clark. The ignited salt, *pyrophosphate* of soda, redissolved in water, crystallises in another shape, and with a different number of atoms of water, from the common phosphate. Its solution, also, on being added to solutions of silver, produces a white precipitate of neutral phosphate of silver, whereas the common phosphate produces a yellow precipitate of subphosphate of silver.

Borate of Soda—Borax.—Neutral borate of soda is an artificial production, not much known; but the sub-borate of soda, or common borax, is a body that is well known, and very useful. It is brought from the East Indies in an impure state, and called *tincal.* It is purified by being boiled very strongly, and for a long time. It is white, transparent, has a greasy feel, and a styptic alcaline taste; it converts vegetable blues to green; it is soluble in 6 parts of boiling water, and 18 of cold water. Its crystals are transparent and hard. When exposed to heat, it swells, boils, loses its water of crystallisation, and becomes converted into a porous, white, opaque mass, termed calcined borax. With a stronger heat it melts into a transparent glass, but remains soluble in water. It is much used as a flux for metals, and is therefore of great importance in analysis by the blowpipe.

Carbonate of Soda.—This compound is known in commerce by the names of *kelp*, *barilla*, and *soda*, and is obtained either from the decomposition of common salt, or from the combustion of marine plants. It exists in three states—1. The *carbonate;* 2. the *bicarbonate;* and, 3. the *sesquicarbonate.* The composition of which, free from water of crystallisation, is shown by the following scheme, in which Na signifies 6 parts of sodium; C, 3 parts of carbon; O, 4 parts of oxygen; and H, $\frac{1}{4}$ part of hydrogen:—

$$\mathrm{Na\,Na\,C\,O\,O\,O} = \text{Carbonate of soda} = \mathrm{Na^{2}\,C\,O^{3}}$$

$$\left.\begin{array}{l}\mathrm{Na\,Na\,C\,O\,O\,O}\\ \mathrm{\;\,H\;\,H\;\,C\,O\,O\,O}\end{array}\right\} = \text{Bicarbonate of soda} = \mathrm{NaHCOOO} = \mathrm{Na\,H\,C\,O^{3}}$$

$$\left.\begin{array}{l}\mathrm{Na\,Na\,C\,O\,O\,O}\\ \mathrm{\;\,H\;\,H\;\,C\,O\,O\,O}\\ \mathrm{Na\,Na\,C\,O\,O\,O}\end{array}\right\} = \text{Sesquicarbonato of soda} = \mathrm{Na^{4}H^{2}C^{3}O^{9}}$$

1. *Carbonate.* Crystallises. Its taste is urinous and slightly acrid, without being caustic. It changes blue vegetable colours to green. It is soluble in twice its weight of cold water, and less than its weight of boiling: hence a saturated hot solution crystallises on cooling; the crystals are, however, more beautiful, when the evaporation is carried on slowly. Its crystals sometimes contain 63 per cent. of water. It is one of the most efflorescent salts known, falling completely to powder in a very little time after its exposure to the atmosphere. On the application of heat, it is soon rendered fluid, is dried by the continuance of the heat, and then melted. As it is more fusible than the carbonate of potash, it is preferred to that salt in the manufacture of glass, because it promotes the fusion of the earth in a greater degree, and produces a glass of better quality.

2. *Bicarbonate.* Small, more sparingly soluble crystals. Prepared by exposing crystals of carbonate to a current of carbonic acid gas.

3. *Sesquicarbonate.* Found native in Hungary and Egypt, called in commerce *Trona.* Prepared by boiling a solution of the bicarbonate. Crystallises. Is more readily soluble than the bicarbonate.

To obtain pure Carbonate of Soda.—Dissolve soda of commerce in a small quantity of water, and filter the solution. Slowly evaporate the filtered solution by a low heat; if small crystals of chloride of sodium form on the surface, skim them off. When these cease to form, the solution may be suffered to cool, and the purified carbonate of soda will crystallise. The powdered crystals are used in experiments with the blowpipe, and in reducing processes; a solution formed by dissolving the crystals in distilled water, is employed as a test.

SILICATE OF SODA.—The same as common hard window glass.

Hydrate of Soda.—Prepared by adding slaked lime to a solution of carbonate of soda boiling in an iron kettle. Its properties resemble those of hydrate of potash.

POTASSIUM.

The properties of potassium are very extraordinary. It is lighter not only than all other metals, but even than water. It is solid, soft, and of the colour and lustre of silver. But its metallic nature is not retained a single minute when it is exposed to the air; it instantly absorbs oxygen, and becomes covered with a crust of *potash*. This oxide absorbs water, which is rapidly decomposed, and in a short time the whole becomes a saturated solution of potash. Potassium is exceedingly inflammable; it fuses at 136°, and rises in vapour at a heat below redness. When heated in oxygen gas to the temperature at which it begins to evaporate, it burns with a brilliant light and an intense heat. When thrown upon the surface of water, it acts with great violence. The liquid is rapidly decomposed; its hydrogen is evolved, and spontaneously inflames in the air; it then communicates the combustion to the potassium, and the whole burns, while swimming about on the water, with a beautiful light of a violet-red colour; meantime, the oxygen unites with the potassium, and produces an oxide, which dissolves in the water, and produces a solution of potash.—Potassium likewise burns with a kind of explosion, when placed, in a perfectly cold state, upon a piece of ice, dissolving the ice, and forming a little hole, in which it burns till entirely consumed, forming, as before, a solution of potash. It spontaneously inflames when put into chlorine gas, burning with great brilliancy, and producing chloride of potassium. Upon all fluids containing water, or much oxygen or chlorine, potassium acts with great rapidity; and, in its general powers of chemical combination, it may be compared to the *alcahest*, or *universal solvent*, so much talked of and longed for by the alchemists. Potassium has, of all known substances, the strongest tendency to combine with oxygen; and it can only be preserved in the metallic state by being kept in naphtha, a liquid of which oxygen is not a constituent.

The following table shows the composition of some of the most important compounds of potassium :—

Potassium.	Oxygen	Other Elements.	Name and Weight of the Products.
20	4		24· Protoxide of potassium
20	12		32· Peroxide of potassium
10	4	0·25 Hydrogen	14·25 Caustic potash
10		4· Sulphur	14· 1st Sulphuret of potassium
10		8· Sulphur	18· 2nd ditto
10		12· Sulphur	22· 3rd ditto
10		16· Sulphur	26· 4th ditto
10		20· Sulphur	30· 5th ditto
10	8	4· Sulphur	22· Sulphate of potash
10	16	8· Sulphur 0·25 Hydrogen	34·25 Bisulphate of potash
10		9· Chlorine	19· Chloride of potassium
10	12	9· Chlorine	31· Chlorate of potash
10	8	3· Carbon	21· Oxalate of potash
20	12	3· Carbon	35· Carbonate of potash
10	12	3·5 Nitrogen	25·5 Nitrate of potash

Protoxide of Potassium—Anhydrous Potash.—Produced when potassium is burned in oxygen gas. Greyish-white, fusible, hard mass. Dissolves in water with great heat.

Sulphuret of Potassium.—Mix a bit of potassium with a little sublimed sulphur in a tube, and heat it over a spirit-lamp. The combination takes place with combustion, and sulphuret of potassium is produced. Other varieties of sulphuret of potassium are obtained (*a*) by igniting sulphate of potash with charcoal, or in hydrogen gas (the 1st sulphuret, a dark red soluble and fusible substance); (*b*) by melting together equal parts of carbonate of potash and sulphur at a moderate heat. This produces the 5th sulphuret, a brown, brittle mass, formerly

called *liver of sulphur.* It tastes and smells strongly of sulphuretted hydrogen, and gives a yellow solution with water.

SULPHATE OF POTASH.—Hard, sparingly soluble, bitter crystals. Obtained as a residue in the preparation of nitric acid.—*Bisulphate of potash.* Acid, easily soluble, easily fusible crystals; its composition is equivalent to 1 atom of sulphate of potash, and 1 atom of oil of vitriol combined together. I believe that all the bisulphates are constituted in the same way. Bisulphate of potash is reduced to sulphate by a long-continued red heat. It crystallises from a mixed solution of sulphate of potash and sulphuric acid.

NITRATE OF POTASH. SALTPETRE. NITRE.—Columnar, striped, frequently hollow crystals, which contain no water of crystallisation; fixed in the air; taste, cool, sharp, saline. One hundred parts of water at 32° (the freezing point) dissolve 13 parts of nitre; the same quantity at the boiling point dissolves about 240 parts. The crystals melt at a dull red heat, and start, on cooling, into an opaque crystalline mass, unaltered in composition. At a bright red heat it suffers decomposition, disengaging oxygen gas, which at first is tolerably pure, but gradually becomes more and more contaminated with nitrogen gas. By this decomposition, the salt is first reduced to nitrate of potash, and finally to pure protoxide and peroxide of potassium. When the crystals are suddenly exposed to a red heat, in mixture with charcoal, sulphur, phosphorus, iron, or zinc, a smart deflagration is produced. Nitre is the principal ingredient in the composition of gunpowder. It also enters into the composition of fluxes, and is extensively employed in metallurgy; it serves to promote the combustion of sulphur in fabricating sulphuric acid; it is used in the art of dyeing; it is added to common salt for preserving meat, to which it gives a red hue; it is an ingredient in some frigorific mixtures; and is frequently prescribed in medicine. It is also from this body that the nitric acid of commerce is generally obtained.

Nitrate of potash is obtained by adding nitric acid to a solution of carbonate of potash as long as effervescence continues. The solution is then filtered and crystallised. To obtain nitrate of potash cheaply, for purposes of experiment, in a state of purity, dissolve common saltpetre in boiling water, nearly to the point of saturation; filter the solution while hot; and add a few drops of a solution of caustic potash. If precipitation ensues, continue to add the potash till it ceases. If no precipitation takes place, or when it is at an end, filter the solution, and crystallise by slow evaporation.

CHLORIDE OF POTASSIUM.—Crystallises in colourless, transparent cubes, tastes like chloride of sodium, readily soluble in water, fusible at a red heat. Produced by the spontaneous combustion of potassium in chlorine gas, by the ignition of carbonate of potash in chlorine gas, or by the solution of carbonate of potash in muriatic acid.

CHLORATE OF POTASH.—Its crystals have the appearance of pearly spangles, like the crystals of boracic acid. It has the taste of nitre, is sparingly soluble in cold water, more readily in hot water; it fuses at a low heat undecomposed, but at a bright red heat it gives off very pure oxygen gas, and yields a mixture of chloride of potassium and perchloride of potash, which, by a continued heat, is wholly converted into chloride of potassium. Chlorate of potash yields nearly 39 per cent. of oxygen, or 100 grains give 132 cubic inches of gas. When mixed with inflammable bodies, such as sulphur, phosphorus, &c., it is exploded with a loud noise and production of fire, either by striking, rubbing, heating, or the application of an acid.

Preparation of Chlorate of Potash.—Pass a current of chlorine gas through a nearly-saturated solution of common carbonate of potash; using the apparatus, and taking the precautions recommended for the "solution of gases in water," page 53—57. The conducting tube that goes into the solution must be half an inch wide, because if narrower it is apt to be choked up by crystals of chlorate of potash that form during the process, which might occasion an explosion. The chlorine gas is rapidly absorbed by the liquid alcali, and carbonic acid escapes with effervescence. The liquor is generally of a pinkish hue, from the presence of manganese. This process produces a mixed solution of chloride of potassium and chlorate of potash, which may be separated by crystallisation, the former being much more soluble than the latter. When the solution is saturated, it may be set aside, in a cool dark place, for 24 hours, at the end of which it will be found to have deposited a considerable portion of crystallised chlorate of potash, which may be taken out, drained, and purified by solution in boiling water, which, upon cooling, deposits the salt in brilliant crystalline scales. Or the solution, when saturated with the gas, may be gently evaporated, and the first products of crystals only be reserved for use, as the subsequent products consist merely of chloride of potassium. The precautions necessary to be taken in exhibiting the explosive power of this salt will be described in another section.

BROMIDE, IODIDE, and FLUORIDE OF POTASSIUM, all crystallise in cubes, with properties very similar to the chloride of potassium.

CHROMATE OF POTASH.—Beautiful yellow crystals, of the form of sulphate of potash, easily soluble in water, giving a yellow solution, possessed of extraordinary colouring properties.—*Bichromate of potash.* Forms large easily-fusible crystals, distinguished by a splendid red colour, which it communicates to its aqueous solution. The latter is obtained by adding nitric acid to the solution of the neutral salt, and crystallising the mixture.

When chromate of potash is mixed with sulphuric acid and alcohol, it becomes hot and turns green, in which state it gives crystals of chrome-alum. When chromate of potash is ignited with sal ammoniac and carbonate of potash, it is decomposed, and the ignited mass contains insoluble green oxide of chromium.

Chromate of potash not only serves as a colouring matter itself, but gives rise to many others. It is used in dyeing, in which, with salts of lead, it produces most beautiful yellow and red colours. It is also the material employed to produce all other compounds of chromium.

CARBONATE OF POTASH.—The *neutral* carbonate of potash, namely, that constituted of

Potassium.........	20
Carbon	3
Oxygen............	12

is a white, uncrystallisable, extremely deliquescent mass, the taste and reactions of which are strongly alcaline. It fuses at a red heat, but is not decomposed. It runs to liquid in moist air, and dissolves in less than its own bulk of water. When an acid is added, it produces carbonic acid gas with effervescence. The potash of commerce, a green, blue, and red party-coloured caustic mass, is an impure variety of carbonate of potash. *Pearlash* is the same thing, freed from a portion of its impurities. The contaminating substances are sulphate of potash, chloride of potassium, sulphuret of potassium, besides vegetable, earthy, and metallic substances, from a portion of which it can be separated by solution in water, decantation, and evaporating to dryness. A purer sort of carbonate of potash is prepared by igniting tartrate of potash, and dissolving and filtering the residue. The *Sal tartari* of the apothecaries is carbonate of potash in a state of impurity. To prepare a test-solution of the carbonate, buy crystallised bicarbonate of potash, ignite it in a platinum crucible over a large spirit-lamp; dissolve the residue in distilled water, and filter the solution.

Bicarbonate of Potash.—Obtained by saturating the moistened carbonate with carbonic acid gas. Water is essential in the preparation of this gas; as, in fact, like the carbonate of soda, it is constituted of a carbonate of the metal with a carbonate of hydrogen, thus:—

$$\mathrm{K\,K\,C\,O\,O\,O} = \text{carbonate of potash.}$$

$$\left.\begin{matrix}\mathrm{K\,K\,C\,O\,O\,O}\\ \mathrm{H\,H\,C\,O\,O\,O}\end{matrix}\right\} = \left\{\begin{matrix}\mathrm{K\,H\,C\,O\,O\,O}\\ \mathrm{K\,H\,C\,O\,O\,O}\end{matrix}\right\} \text{bicarbonate of potash;}$$

in which K is 10 of kalium or potassium; H, $\frac{1}{4}$ of hydrogen; C, 3 of carbon; O, 4 of oxygen, all *by weight.*

Bicarbonate of potash forms transparent crystals, non-deliquescent, which heat converts into carbonate of potash, under disengagement of water and carbonic acid gas; even boiling in water effects a partial decomposition. The bicarbonate is much milder in its taste and reactions than the carbonate.

Direct Formation of Carbonate of Potash.—Process 1. Fill a common phial with carbonic acid gas. Apply the thumb to its mouth, and invert it in a solution of pure potash, contained in a cup, and rather exceeding in quantity what is sufficient to fill the phial. The liquid will instantly rise in the phial, and the gas, if it be pure, will disappear entirely, being all absorbed. Pour out the alcaline liquor into the cup, fill the phial again with gas, and again invert it in the solution. The absorption will take place again. Repeat the process till the alcali is saturated.—*Process* 2. Pass a current of carbonic acid gas into a solution of caustic potash.

OXALATE OF POTASH exists in two states; one, the super-oxalate, sometimes called *essential salt of lemons*, is obtained from the leaves of wood-sorrel; the other, the oxalate, may be obtained by adding carbonate of potash to the super-oxalate. Both may be formed by the direct union of potash with oxalic acid, certain precautions being observed. Oxalate of potash is a crystallisable salt; but it does not readily crystallise unless one of the ingredients be in excess. The crystals are nearly insoluble in cold water, but will dissolve in 10 parts of boiling water. The taste of this salt is sharp, acrid, and bitter. It is used for removing stains from linen, and for various purposes of the arts. It is equivalent in composition with sulphate of potash, excepting that, to the same weight of oxygen and potassium, it contains 3 of carbon instead of 4 of sulphur.

CYANIDE OF POTASSIUM.—Produced when potassium is burned in cyanogen gas. Prepared by exposing yellow prussiate of potash (double cyanide of potassium and iron) to a melting heat. Colourless, crystallises in cubes, which are not very readily formed; reactions alcaline; taste and smell like prussic acid. Readily soluble in water, forming a solution which is decomposed by boiling.

SULPHOCYANIDE OF POTASSIUM.—Colourless, crystallisable; gives sulphocyanic acid when distilled with a concentrated solution of phosphoric acid.

Preparation.—Mix equal parts of sublimed sulphur and yellow prussiate of potash. Heat the mixture in a glass vessel over a spirit-lamp, nearly to the boiling point of the sulphur. Dissolve the mass in water, which will contain a mixture of sulphocyanide of potassium and sulphocyanide of iron. The addition of caustic potash causes the precipitation of hydrate of iron, and leaves pure sulphocyanide of potassium in solution.

The sulphocyanides of other metals can be made by double decomposition with this solution.

SILICATE OF POTASH.—A constituent of several minerals—as Feldspar, &c. Can be formed by igniting pulverised quartz with carbonate of potash; the mixture fuses, and carbonic acid gas is produced. *Liquor of Flints.*—Fuse together 10 parts of carbonate of potash, 10 parts of fine quartz powder, and 1 of charcoal powder. When effervescence ceases, pour out the liquid on an iron plate. This compound has the appearance of glass, but it deliquesces in the air, and dissolves in water. Its solution can be employed to give a coating of glass to wood, carpets, &c., and thereby render them incombustible.

HYDRATE OF POTASH.—Prepared as follows:—Dissolve 1 part of pure carbonate of potash in 6 parts of water, and boil the mixture in a silver or iron kettle provided with a cover. While it is boiling, gradually add pure slaked lime in very small portions, until $1\frac{1}{2}$ parts of burnt lime have been added to 1 part of carbonate of potash. Carbonate of lime is deposited, and hydrate of potash left in solution. A little of the liquor taken out and filtered must give no precipitate with lime water. Filter the solution through a linen bag, allow it to settle in a covered vessel if muddy. decant the clear solution; rapidly evaporate it to dryness in a covered bright iron or silver capsule; and heat the dry hydrate in a silver crucible till it melts.

Hydrate of potash, or caustic potash, is white, hard, and brittle; deliquesces very rapidly in the air; dissolves in water with much heat; is soluble in alcohol; taste excessively corrosive; acts on vegetable and animal bodies so as to alter them greatly or destroy them. Its solution attacks glass. It corrodes earthen vessels when melted in them. From atmospheric air, it attracts both carbonic acid and water with great eagerness. It melts below a red heat, and runs like oil; in a very strong heat it volatilises, but loses no water. It decomposes the salts of all other metals.

If you want a small quantity of potash for experiments, buy it in the solid state. Dissolve it in water; allow the impurities to subside; and decant the clear solution into the bottle in which it is to be preserved. Its solution acts so powerfully upon animal and vegetable substances, that it cannot be filtered through paper. Grease the stopper with tallow to prevent its sticking in the bottle. When you wish to remove a little of the solution of potash out of the bottle, make use of the dropping tube described at page 26; never pour the solution from the mouth of the bottle, otherwise what remains on the neck will fasten in the stopper, so that it cannot again be removed without breaking.

Hydrosulphuret of Potassium.—I scarcely know what to call this substance. Every chemist gives it a different name. It exists in the state of large colourless crystals, which have a sharp alcaline taste, and which deliquesce in the air. They are produced by saturating caustic potash with sulphuretted hydrogen gas. Its composition is potassium 10 parts, sulphur 8 parts, and hydrogen one-fourth part. It contains, therefore, as many elementary atoms as sulphate of potash. Thus:—

$KO + SO$ = Sulphate of potash.
$KS + HS$ = Hydrosulphuret of potash.

The compound under consideration is the type of a large class of compounds, constituted in a similar way.

Tartrate of Potash.—There are two varieties of this salt, the tartrate, commonly called *soluble tartar;* and the super-tartrate, well known by the name of *cream of tartar.* 1. The super-tartrate of potash is found incrusted on the bottoms and sides of casks in which wine has been kept. The grey or dirty-red crust is purified by solution and filtration, and the salt is procured from it in crystals. The crystals are white, transparent, and sour; they dissolve with difficulty, requiring 60 parts of cold water, or 14 of boiling. It is much used in chemical and medicinal preparations. 2. The *tartrate of potash* forms transparent and very soluble crystals. Obtained by adding carbonate of potash to purified cream of tartar.

Chloride of Potash and Platinum.—A yellow powder, very sparingly soluble in water, produced when solutions of potassium are added to a solution of chloride of platinum. This compound contains 3 atoms of chlorine, 2 of platinum, and 1 of potassium. A similar compound is produced by ammoniacal salts, containing 3 atoms of chlorine, 2 of platinum, and 1 of ammonium.

Cyanide of Iron and Potassium. Prussiate of Potash. Ferrocyanate of Potash.—On boiling Prussian blue in a solution of caustic potash, it loses its colour, oxide of iron in the state of hydrate is precipitated, and a yellow solution rests above. The evaporation of this solution gives citron-yellow tabular crystals, which contain the same constituents as two atoms of cyanide of potassium, one atom of cyanide of iron, and three atoms of water; the latter, however, can be expelled by heat. Compounds similar to the one under consideration are formed by the combination of one atom of cyanide of iron with two atoms of the cyanide of some other metal. See page 107.

Prussiate of potash is made in the large way by igniting animal matters with potash and iron, and washing the residue. A solution of this salt produces Prussian blue when mixed with a solution of a persalt of iron. Hence its use in the art of dyeing. It is also one of the most valuable reagents which the chemist possesses for metallic analysis. In large crystals, it possesses a kind of toughness, and, in thin scales, of elasticity. Water, when cold, dissolves one-third of its weight of this salt, and an equal weight at the boiling point. Its solution is not affected by alcalies; but it is decomposed by almost all the salts of the permanent metals,—the cyanogen of the potassium and the cyanide of iron precipitating with the metal, generally with some striking and peculiar colour. Hence the use of prussiate of potash as a test.

Red Cyanide of Iron and Potassium.—Formed when a solution of the yellow cyanide is exposed to a current of pure chlorine gas. Gives large transparent crystals, possessed of a splendid morning-red colour and great brilliancy. The powder is of an orange-colour. The crystals contain no water. Its solution is yellow when dilute, brown when concentrated. It gives a blue precipitate with solutions of the protosalts of iron, whereas a solution of the yellow cyanide gives a blue precipitate only with solutions of the persalts of iron.

Preparation.—Pass a current of chlorine gas into a solution of yellow cyanide of iron and potassium, until the solution, from being greenish, becomes red (which is best to be seen by candle light), or until it ceases to give a blue precipitate with a solution of perchloride of iron (page 148). If the solution is intended for a *beer-test*, namely, to detect *iron* or *copperas*, added as an adulterant to beer, it is not necessary to add so much chlorine as is required to decompose the whole of the yellow prussiate of potash, because the presence of a portion of the latter is an advantage. But if you wish to obtain the red salt in a state of purity, you must proceed as I have stated. It is best to put twenty or thirty drops of a solution of perchloride of iron round the edge of a plate, and to provide a number of glass rods. Every time you shake the bottle after removing it from the gas tube (p. 53), you should dip a glass rod into the solution, and touch one of the drops of perchloride of iron. When the solution ceases to turn the drops blue-green, it contains as much chlorine as it ought to contain. The solution must not retain a strong smell of chlorine, otherwise it contains too much of that element. This is a misfortune, because an excess of chlorine converts the red cyanide into chloride of potassium and prussian blue. If, therefore, you should accidentally give the solution too great a quantity of chlorine, you must neutralise it by adding a fresh solution of yellow cyanide.

Filter the resulting solution of red cyanide, pour it into a confectioner's glass, and evaporate it at a low temperature. You will then observe the formation of needle-shaped crystals of a red colour. Remove these crystals from the solution, dissolve them in water, filter the solution, and slowly evaporate it in a confectioner's glass. It will afford crystals, which must be again dissolved, filtered, evaporated, and crystallised. Finally, if you operate on a considerable quantity of the salt, you will obtain large and beautiful crystals of a magnificent red colour. But the purification and crystallisation of this salt are most troublesome and tedious operations, particularly if you do not employ a glass vessel with steep sides, or if you heat the solution too much. The salt decomposes at the heat of boiling water, when in solution.

Crystallisation, however, is quite unnecessary to be performed with a solution which is only intended for a beer-test. You may content yourself in this case, with passing into the solution merely that quantity of chlorine which is necessary to give the solution a reddish colour. The beer-test is then prepared.

MANGANESATE OF POTASH.—1. Intimately mix 1 part of finely-powdered peroxide of manganese, with 3 or 4 parts of nitre. Put the mixture into a crucible capable of holding 3 times the quantity, and expose it to a bright red heat for half an hour, or as long as any gas continues to be disengaged. The product has a green colour. It contains an excess of alcali, and must be kept from the air in close vessels. 2. Melt together equal parts of caustic potash and peroxide of manganese. The product will be black.

The manganesate of potash is commonly called the *Mineral Chameleon*, in consequence of the remarkable changes of colour which take place when it is dissolved in water and exposed to the air. It first produces a *deep green* solution, which gradually passes through various shades of *green*, *blue*, *violet*, and *purple*, till it finally becomes of a *splendid red colour*.

The deep green solution produces crystals of the form of sulphate of potash, and it appears that its composition is equivalent to that of the latter salt, thus:—

$KO + SO =$ sulphate of potash.
$KO + MnO =$ manganesate of potash.

While the solution of this salt is in the act of changing from green to red, on exposure to air, it absorbs carbonic acid, which decomposes a portion of the manganesate, and produces carbonate of potash, a precipitate of hydrate of manganese, and a new salt, *super-manganesate of potash*, which is the compound that produces the red solution, and which is probably composed of

$$KO\,MnO + MnO.$$

Namely, it contains half as much more oxygen, and twice as much manganese, as the manganesate, the quantity of potassium remaining the same. Nevertheless, I must confess that the analyses of this compound that I have seen related, are not of the most intelligible and satisfactory description.

Sulphate of Alumina and Potash.—Alum.—This salt is sometimes found in a native state, but is generally formed from various minerals, called alum ores. It crystallises in regular octahedrons, has a sweetish, but very astringent taste, and reddens vegetable blues. It is soluble in from 15 to 20 parts of cold water, and in much less than its weight of boiling water. Its crystals effloresce in the air, and, when heated, melt in their water of crystallisation: at a strong heat, they lose 45 per cent. of their weight of water, and are reduced to a white porous mass, called *burnt alum*. This salt is a very important one: it is extensively used in medicine, bleaching, dyeing, calico-printing, tanning, paper-making, and various other arts. Bodies which have been steeped in a solution of alum, are not apt to take fire.

THE

ROMANCE OF CHEMISTRY.

I HAVE hitherto been treating of matters of fact, but am now about to treat of matters of opinion. Speculative chemistry is a wide field, upon which many have entered and gone astray. It would be too much for me to flatter myself with having taken a surer path than any of my predecessors; but I have chosen the way which appeared to me most likely to lead to truth, and that way I will now point out to others. I entitle this chapter the "Romance of Chemistry," that the reader may know he is upon debatable ground, and may take heed how he gives the rein to his belief.

When a man comes forward with a proposal to change the whole theory and nomenclature of a science, he may be expected to say something in reply to those who may be of opinion that change of either is unnecessary. To such as these I shall reply by a few quotations, adopting that course merely to furnish more impartial evidence than my own.

Against the general charge of meddling unnecessarily with established doctrines and established names, I defend myself by an opinion of Berzelius, which seems to justify my presumption.

"Even when a theory is universally accepted, it is often very useful to a science to prove that its phenomena are explicable upon other principles." BERZELIUS, *Lehrbuch der Chemie*, B. III. p. 28, 1827.

Next, in relation to the excellencies of the existing nomenclature, hear!—

" The present chemical nomenclature is allowed on all hands to be inadequate to the wants of chemistry." Dr Thomas Thomson, *System of Chemistry of Inorganic Bodies*, vol. I., page iv., 1831.

" The nomenclature of chemistry is no longer in harmony with the science, and we cannot too strongly urge the student to learn it simply as a language and not as the expression of a system." Dumas, *Traité de Chimie*, 1828, t. I. p. xxiii.

" The Latin antiphlogistic nomenclature, which formed the basis of the French nomenclature, is a real masterpiece. He who, with a slight knowledge of chemistry, runs over it, instantly learns it; and it forms, I may say, an essential part of the theory of the science. This theory, however, having made immense progress since the first publication of the nomenclature, it has become necessary to augment the latter in proportion; and I proceed now to specify the alterations made in the nomenclature to adapt it to the present state of the theory.——" Berzelius, *Essai sur la Théorie des Proportions Chimiques*, p. 155. 1819.

Instead of copying Berzelius's Views of Nomenclature in 1819, I shall quote a few of his improved names published so lately as 1831. Should the reader consider these names adapted to fulfill the purposes of chemical explicitness, he need scarcely take the trouble to pursue the " Romance of Chemistry" any farther.

" Hypersulfomolybdate cobaltique.—Sulphotellurate tricobaltique.—Chlorure niccolico-ammonique.—Fluorure Zincico-potassique.—Fluorure aluminico-zincique.—Sulfocyanhydrate zincique.—Sulfarséniate zincique.—Sulfarsénite zincique.—Chlorure plombique.—Chlorure plombique bibasique.—Chlorure plombique tribasique.—Chlorure plombique surbasique.—Fluorure borico-plombique.—Phosphate plombique.—Surphosphate plombique.—Phosphate sesquiplombique.—Hypophosphite seplombique.—Hyposulfantimonite sesquiplombique.—Hypersulfomolybdate stanneux.—Hypersulfomolybdate stannique. — Sulfomolybdate stanneux.—Sulfomolybdate stannique.—Sulfotellurate tristanneux. — Sulfotellurate tristannique.—Chlorure Bismuthique.—Chlorure Bismuthique basique.—Phosphate uranico-calcique sesquibasique.—Fluorure silicico-cuivreux.—Fluorure silicico-cuivrique. — Soushyposulfate cuivrico-ammonique. — Hyposulfantimonite tricuivrique.—Iodure mercureux.—Iodure susmercureux (mercuroso-mercurique).—Iodure mercurique.—Sulfarséniate mercureux.—Sulfarséniate mercurique. —Sulfarsénite mercureux.—Sulfarsénite mercurique. —Sulfomolybdate mercureux.—Sulfomolybdate mercurique. —Hypersulfomolybdate mercureux. — Hypersulphomolybdate mercurique.—Sulfotellurate trimercureux.—Sulfotellurate trimercurique."—BERZELIUS, *Traité de Chimie, traduit par* ME ESSLINGER, *sur les manuscrits inédits de l' auteur*, t. iv. 1831.

NEWLY-IMPROVED ENGLISH CHEMICAL NAMES.—" Ammonia-sesquisulphated peroxide of iron.—Ammonia-trisulphate of alumina.—Ammonia-disulphated sesquioxide of manganese.—Potash-sesquisulphate of peroxide of iron.—Potash-sesquisulphated sesquioxide of manganese.—Baryto-subsulphated peroxide of platinum.—Perferro-sulphate of alumina.—Ferro-sulphate of nickel and copper.—Calcareo-hyposulphite of silver. — Quater-chloro hydrargyrate of potassium.—Bichloro-hydrargyrate of sal ammoniac.—Quinto-chloro-hydrargyrate of calcium.—Terchloro-hydrargyrate of magnesium.—Sesquichloro-osmiate of ammonia. —Terchloro-iridiate of potassium.—Fluo-silicated peroxide of iron.—Fluo-silicate of suboxide of copper.—Fluo-titaniated peroxide of iron.—Ferro-cyanodide of potassium. —Bisulpho-carbonate of potassium.—Sulpho-arseniate of bisulphuret of iron.—Sulpho-arseniate of subsulphuret of mercury.—Ammonia-sulpho-arseniate of sodium.—Sulpho-arsenite of disulphuret of mercury.—Sulpho molybdate of sesquisulphuret of cerium.—Hypersulpho-molybdate of ammonia.—Sulpho-tungstate of potassium combined with tungstate of potash.—Sulpho-tungstate of bisulphuret of iron."—Chemistry is indebted for this addition to its nomenclature to Dr THOMAS THOMSON, by whom these " new terms were contrived to render the present state of the science intelligible."—*System of Chemistry of Inorganic Bodies*, vol. I., page iv., 1831.

" I agree with Professor WHEWELL, that the time is not far distant when it will be impossible to dispense with symbols in chemistry ; for the existing nomenclature, how ever ingeniously constructed it may be, seems incapable of adapting itself to the expression of the various combinations which will probably be discovered, and even now is with difficulty rendered applicable to compounds of more than two ingredients.

" 'In this latter, the most simple case supposable,' observes Professor WHEWELL, 'though there may be no difficulty in expressing the composition clearly by the usual language of chemistry, yet the nomenclature is often imperfect.

" 'Thus the words *hyposulphate*, *sulphite*, *sulphate*, are defective, in not showing the relative quantity of oxygen in the acid; and, moreover, such terms are liable to become improper, by the discovery of new compounds. The same may be said of such expressions as *per*oxide, *per*sulphate.

" 'Nor is this nomenclature capable of extending itself, by virtue of its own rules, in proportion as discovery extends. If new combinations of manganese and oxygen should hereafter be discovered, they must receive arbitrary, and probably anomalous, designations. The oxide, deutoxide, peroxide, manganesious, and manganesic acid, do not at all obviously refer to compounds, in which the proportions of oxygen are 1, 1½, 2, 3, 4; and if we should find a combination in which the proportion of oxygen is 2½ or 3½, there is no denomination ready for it, nor would it be very easy to find a good one. This applies equally to very many cases.

" 'In other cases phrases are used, such as the *sulphato-tricarbonate of lead* for instance, which, though capable of a right interpretation, do not sufficiently interpret themselves; and even such can only be constructed for a few detached instances.

" 'When the constitution is at all less simple than in the above examples, the expression to describe it becomes still more difficult to construct. If we have 3 proportionals of lime and 4 of silica, there is no very compendious chemical name for the compound.' "—DAUBENY, *Introduction to the Atomic Theory*, p. 53, 1831.

" If a nomenclature be not subservient to the uses of science, and does not keep pace with its progress, the relation between substances and their names will become so relaxed, that confusion will be brought about by the very means we take to avoid it; and if, while we continue to extend our acquaintance with chemical bodies, nomenclature remains confined within its former limits, the bonds that unite these two parts of the science must inevitably be broken."—CHENEVIX, *Phil. Trans.*, 1802.

Reader! Imagine a school-boy who has outgrown his clothes. Imagine the *repairs* made on the vestments where the enlarged frame had burst the narrow limits of its inclosure. Imagine the *additions* made where the projecting limbs had fairly and far emerged beyond the confines of the garment. Imagine the boy *still growing*, and the clothes, mended all over, now *more than ever in want of mending*—such is chemistry, and such its nomenclature.

With a view to justify my interference with the ESTABLISHED THEORY of chemistry, I shall show that, like its nomenclature, it is not without its defects, and possesses at least as great a tendency to mystify as to enlighten. I shall limit my exposition to a single example, but that example shall be taken from the works of the first of living chemists. What the theory is good for in other cases may be judged of by this single instance. A system that is able to lead astray a man possessing the knowledge, shrewdness, and ingenuity of BERZELIUS, must needs be "too bad."

Experimental chemistry proves that the substance called ALUM contains the elements *potassium*, *aluminum*, *sulphur*, *hydrogen*, and *oxygen*. Theoretical chemistry, or at least the established theory of chemistry, pretends to explain how these elements are combined together in the aforesaid compound. Thus says BERZELIUS, (*System of Mineralogy*, p. 25, published in England in 1814):—

"It is clear that if, in stating the composition of salt of alum, for example, we were not to go farther than to consider it as consisting of potassium, aluminum, sulphur, hydrogen, and oxygen, in a scientific point of view, we should derive but little advantage from such a statement. We come a step nearer to the nature of the compound, when we consider it as composed of sulphuric acid, alumina, potash, and water. The composition of this salt was long supposed to be this by chemists, and from that circumstance it received the name of triple salt, or a salt which consisted of three principal ingredients. The next step to a more perfect knowledge of the nature of alum was the considering it as consisting of sulphate of potash and sulphate of alumina with water of crystallisation, whence it received the appellation of double salt. Lastly, the doctrine of the chemical proportions completed, if I may so speak, our knowledge of the composition of this salt, by showing that it consists of one particle of sulphate of potash, three particles of sulphate of alumina, and twenty-four particles of water of crystallisation."

This explanation must be a stumbling-block to all who require proofs before they believe. What grounds have we for Berzelius's conclusions? Let us see how many assumptions this short paragraph contains. They are as follows:

1. Alum contains sulphuric acid.
2. It contains alumina.
3. It contains potash.
4. It contains water.
5. It contains sulphate of potash.
6. It contains sulphate of alumina.
7. It contains water of crystallisation.
8. It contains one particle of sulphate of potash.
9. It contains three particles of sulphate of alumina.
10. It contains 24 particles of water of crystallisation.

This is pretty well. "Little advantage is to be derived" from knowing what is *demonstrated* by experiment, namely, that alum contains potassium, aluminum, sulphur, hydrogen, and oxygen; but "our knowledge is completed" by believing ten assertions, all offered without proof! And this is mathematical chemistry! this is experimental philosophy! The example is chosen here by BERZELIUS as giving an idea of "the correct distribution of the ingredients of the minerals." Five years afterwards (1819) he employs alum to illustrate another subject.

"To express compound atoms of the fourth order, we place each atom of the third order within parentheses. For example, the atom of crystallised alum is expressed by $(\ddot{K}\,\dddot{S}^2 + 2\,\overset{\cdot\cdot\cdot}{Al}\,\dddot{S}^3) + 48\,H^2\,O$, being composed of one particle of the third order with 48 particles of water." *Proportions Chimiques*, p. 113.

Let us see what we are called upon to believe here, *in* *addition or contradiction* to what we were desired to believe in 1814.

11. Sulphuric acid contains one atom of sulphur combined with three atoms of oxygen.

12. Alumina contains one atom of aluminum combined with three atoms of oxygen.

13. Potash contains one atom of potassium combined with two atoms of oxygen.

14. Sulphate of potash contains two atoms of sulphuric acid combined with one atom of potash.

15. Sulphate of alumina contains three atoms of sulphuric acid combined with one atom of alumina.

16. Water contains two atoms of hydrogen combined with one atom of oxygen.

17. Alum contains two particles of sulphate of alumina, while in 1814 it contained three particles.

18. Alum contains 48 particles of water, while in 1814 it contained only 24 particles.

19. It contains one atom of potassium.
20. It contains one atom of potash.
21. It contains two atoms of aluminum.
22. It contains two atoms of alumina.
23. It contains eight atoms of sulphur.
24. It contains eight atoms of sulphuric acid.
25. It contains eighty atoms of oxygen.
26. It contains ninety-six atoms of hydrogen.

Without staying to criticise the above account, let us proceed to see what the constitution of alum was found to be in 1827 by the same chemist. I extract the following formula from the *Lehrbuch der Chemie von* Berzelius, B. iii. p. 111. The formula there given is

$$\dot{K}\,\dddot{S} + \dot{A}l\,\ddot{A}l\,\dddot{S}^3 + 24\,\dot{H}\,H$$

Let us again see what we are called upon to believe, in *addition or contradiction* to what we were desired to believe in 1814 and 1819.

27. Alumina contains two atoms of aluminum combined with three atoms of oxygen, while in 1819 it contained but one atom of aluminum to three atoms of oxygen.

28. Potash contains one atom of potassium combined with one atom of oxygen, while in 1819 it contained one atom of potassium to two atoms of oxygen.

29. Sulphate of potash contains one atom of sulphuric acid combined with one atom of potash, while in 1819 it contained two atoms of sulphuric acid combined with one atom of potash.

30. It remains true that sulphate of alumina contains three atoms of sulphuric acid combined with one atom of alumina, although alumina of this date contains two atoms of aluminum, while in 1819 it contained but one atom.

31. Alum contains *one* particle or atom of sulphate of alumina, while in 1819 it contained *two* atoms, and in 1814 *three* atoms of the same substance.

32. Alum contains 24 atoms of water, while in 1819 it contained 48 atoms, and in 1814 only 24 atoms.

33. It remains true that alum contains one atom of potassium and one atom of potash, notwithstanding the alteration in the number of atoms of oxygen contained in potash.

34. Alum contains two aluminum, the same as in 1819, but it only contains one atom of alumina, although in 1819 it contained two atoms of alumina.

35. It contains four atoms of sulphur and four atoms of sulphuric acid, while in 1819 it contained eight atoms of each.

36. It contains forty atoms of oxygen, while in 1819 it contained eighty atoms of the same element.

37. It contains forty-eight atoms of hydrogen, while in 1819 it contains ninety-six atoms of hydrogen.

38. Finally, we are called upon to believe, "that one atom of sulphate of potash is combined with one atom of sulphate of alumina, and that both the salts are neutral, that is to say, in such a state of saturation that the acid contains thrice as much oxygen as the base; that the oxygen of the alumina is thrice that of the potash; that the oxygen of the sulphuric acid is twelve times that of the potash, and four times that of the alumina; that the oxygen of the water is four-and-twenty times that of the potash, eight times that of the alumina, and twice that of the sulphuric acid; that, &c. &c. &c." This last sentence is in Berzelius's own words.

Following up Berzelius's view of the constitution of alum, I come, in the order of time, to Esslinger's French translation of his System of Chemistry, published in 1831, in the fourth volume of which I find, at page 610, the following formula :—

$$\dot{K}\,\dddot{S}^3 + \dot{Al}\,\dddot{Al}\,\dddot{S} + 24\,H\,\dot{H},$$

and at page 613 of the same volume, the formula

$$\dot{K}\,\dddot{S} + \dot{Al}\,\ddot{Al}\,\dot{S}^3 + 24\,H\,\dot{H}.$$

These formula are both widely different from any of the preceding, and as widely different from each other; and though they are employed in the book referred to as a prime example of the benefits of symbols, yet they are evidently misprinted, as the symbols of Berzelius frequently are, and therefore not worth arguing about.

But what are we to think of the constitution of alum after looking at these statements? Is it the number of its elements, or is it the notions of the chemist, that change so often? Is chemical truth of a fixed and invariable nature, or is it liable to change, like the moon, according to the changes of the almanack?

If I attribute these variable statements to the whimsies of the chemist, I shall be asked, if a chemist must not alter the expression of his views, as his knowledge extends, and his views consequently alter? I reply, yes. He should always state what he conceives to be the truth. His theory should always represent the state of his knowledge. But what does the theory of Berzelius gain by this admission? Is it the excellency of a theory to admit of eternal contradictions?

Let the upholders of that "masterpiece," the antiphlogistic nomenclature, prove it to speak "the truth, the whole truth, and nothing but the truth," and I will be silent. But the masterpiece speaks much less and much more than the truth, and the theory upon which it rests sanctions guess-work of the most reckless description. Are these not symptoms that there must be a screw loose in the machinery somewhere?

And a screw, indeed, there *is* loose, and very shaky is the superstructure that hath so many years been the admiration of the world. But its hour is almost come.

Confusion of thought, 'tis said, breeds confusion of speech. Is it not wonderful that nobody should have thought of tracing confusion in Nomenclature to confusion in Theory?

Shall I state in one word wherein the rottenness of the prevailing theory lieth? It is in the *misapplication of the doctrine of* PROXIMATE CONSTITUTION, a doctrine often useful in guiding us through the tortuosities of chemical combination, but of by far too unsteady a nature to be the load-star of a chemical system or a chemical nomenclature. It is an ignis fatuus, ever prompt to lead us astray. Who knows the proximate constitution of alum? Who is ignorant of its ultimate constitution? With the latter, we are upon safe ground; with the former, we slide at every step.

REQUISITES OF A CHEMICAL THEORY.

It must afford a systematic plan for registering the facts discovered by experiment, which facts should be arranged so as to be most completely received by the understanding, and most readily retained in the memory.

It must provide a nomenclature adapted to the communication of our knowledge.

It must represent the truth, the whole truth, and nothing more than the truth.

A perfect theory cannot be contrived while our knowledge of the science is imperfect. Possessed of limited knowledge, we are often unable to distinguish truth from falsehood. Unconsciously, we are led to substitute fiction for fact, and to give to suppositions the credit due only to demonstrations. A chemist should bear this continually in mind, and take heed to keep as close as possible within the bounds of truth. It is his duty, in forming a theory, to be guided by the extent of his knowledge, and not by the warmth of his imagination.

Of imperfect theories, that one is the best which requires the fewest suppositions in aid of its explanation of phenomena.

TABLE OF ELEMENTS.

The following table shows, 1. The names of all the chemical elements, arranged in the order of their relative decomposing powers. 2. The weights of the atoms of the elements, determined by a method to be described hereafter. 3. Symbols for denoting the atoms of the elements. 4. Names for denoting the atoms of the elements.

(+)	Weight of an atom.	Symbol of an atom.	Name of an atom.
Potassium	10	K	Kali
Sodium	6	N	Nati
Lithium	1·5	L	Liti
Barium	17·5	Ba	Bari
Strontium	11	Sr	Stroni
Calcium	5	Ca	Calci
Ammonium	4·5	Am	Ammi
Magnesium	3	Mg	Magi
Glucinum	4·5	Be	Beri
Yttrium	8	Y	Yttri
Aluminum	2·25	Al	Ali
Zirconium	5·5	Zr	Ziri
Thorium	15	Th	Thori
Manganese	7	Mn	Mani
Zinc	8	Zn	Zinki
Cadmium	14	Cd	Cadi
Iron	7	Fe	Feri
Nickel	7	Ni	Nicki
Cobalt	7	Co	Cobi
Cerium	11·5	Ce	Ceri
Lead	26	Pb	Plumi
Tin	14·5	Sn	Stani
Bismuth	18	Bi	Bisi
Uranium	35	U	Uri
Copper	8	Cu	Cupri
Silver	27·5	Ag	Argi
Mercury	25	Mr	Meri
Palladium	6·5	Pd	Palli
Platinum	12·25	Pt	Plati
Rhodium	6·5	R	Rhodi
Iridium	12·25	Ir	Iri
Gold	16·5	Au	Auri
Osmium	12·5	Os	Osmi
Hydrogen	·25	H	Hydri
Silicium	2	Si	Sili
Titanium	3	Ti	Titi
Tantalum	15	Ta	Tani
Tellurium	8	Te	Teli
Antimony	11	Sb	Stibi
Carbon	3	C	Cari
Boron	1	B	Bori
Tungsten	8	W	Woli
Molybdenum	12	Mo	Moli
Vanadium	17	V	Vani
Chromium	7	Cr	Cromi
Arsenic	9·5	As	Arsi
Selenium	10	Se	Seli
Phosphorus	4	P	Phosi
Fluorine	4·5	F	Fluri
Iodine	32	I	Iodi
Bromine	20	Bm	Bromi
Chlorine	9	Cl	Chlori
Azote	3·5	Z	Zoti
Sulphur	4	S	Suli
Oxygen	4	O	Oxi
(−)			
Water	4·5	Aq	Aqui

Numerical exponents, or names denoting any number of atoms, up to 12.

1 = mona
2 = dia
3 = tria
4 = tetra
5 = penta
6 = hexa
7 = hepta
8 = octa
9 = enna
10 = deca
11 = endeca
12 = dodeca

p — signifies the positive element in excess to the extent of 1 atom, if not otherwise mentioned.

n — signifies the negative element in excess to the extent of 1 atom, if not otherwise mentioned.

A more detailed account of some matters shown by this table, and particular notions respecting several important doctrines of chemistry, I will, for brevity sake, throw here into the form of—

DEFINITIONS.

Element.—*A substance unlike every other substance, and which cannot be decomposed into substances different from itself.*

The material world is composed of elements, of which chemists are acquainted, in the year 1834, with fifty-four. See the above table of elements, column 1.

Whenever a substance held to be an element is decomposed into different substances, it is no longer considered an element.

Whenever a new substance, differing from all known substances, and incapable of being decomposed into any substances different from itself, is found, it is considered an element.

Compound.—*A substance formed by the combination of two different substances.*

A compound can contain—

An element with an element.
An element with a compound.
A compound with a compound.

Atom.—*The smallest possible particle of a substance. An indivisible whole.*

As the mind cannot form an idea of a smaller particle than the smallest, the existence of half atoms is inadmissible.

It may appear to some needless to insist upon the absurdities of *half atoms*, and I should not write another syllable on the subject, were it not that several eminent chemists appear to have become desperately enamoured of these impossibilities. Among those who are in this predicament, the French chemist Dumas figures with greatest distinction. The reader shall judge for himself.

Dumas on the Division of Atoms:—

"The considerations relative to the principle that *gases contain the same number of atoms in the same volumes*, are so simple, that it is unnecessary to dwell upon them; but here is a difficulty which presents itself when we attempt to apply them. Take a measure of chlorine, and suppose it to contain 1000 atoms, then a measure of hydrogen ought to contain 1000 atoms, and a measure of hydrochloric acid must contain 1000 atoms also.* Consequently,

1 measure of hydrogen = 1000 atoms,
and 1 measure of chlorine = 1000 atoms,
produce 2 measures of hydrochloric acid = 2000 atoms.

But each atom of chlorine, in combining with an atom of hydrogen, produces but one atom of hydrochloric acid, or 1000 atoms in all. We must, therefore, admit, that the atoms of chlorine and hydrogen become cut into two to form the atoms of hydrochloric acid. Each of these last, then, is formed of half an atom of chlorine and half an atom of hydrogen. The same is the case with deutoxide of azote.

"Let us take another example :—

1 measure of oxygen = 1000 atoms,
and 2 measures of hydrogen = 2000 atoms,
form 2 measures of vapour of water = 2000 atoms.

Each atom of water is composed, therefore, of a whole atom of hydrogen, and the half of an atom of oxygen. The protoxide of azote is in the same case. Finally,

1 measure of azote = 1000 atoms,
and 3 measures of hydrogen = 3000 atoms,
form 2 measures of ammonia = 2000 atoms.

Whence it is necessary to conclude, that each atom of ammonia is composed of an atom and a half of hydrogen and half an atom of azote.

"Consequently, ... we must admit that the atoms of gaseous bodies are susceptible of division on entering into combination.

. . . .

"The atoms of compound gases are formed either of entire atoms, or of
entire atoms united to simple fractions of other atoms, or of
fractions of atoms combined.

---

* The rock upon which DUMAS splits, is the application of his principle, that *gases contain the same number of atoms in the same volumes*, to COMPOUND gases, instead of limiting it to SIMPLE gases. See the definition of ATOMIC MEASURE.—J. G.

. . . .

“ Nothing, therefore, hinders our believing that in compound atoms formed by solid bodies, there enter fractions of atoms, in the same way as in compound gases.”—Dumas, *Traité de Chimie*, 1828, t. i. p. 38—42.

Table of the compounds which contain half atoms, i. e. *particles which are half the size of the smallest possible particles, calculated by* Dumas.

“ Fluorine, Chlorine, Bromine, Iodine.	Half an atom of each of these bodies, and half an atom of hydrogen, form one atom of acid.
Selenium, Sulphur.	Half an atom of each of these and one atom of hydrogen, form one atom of acid.
Oxygen.	Half an atom of this body and one atom of hydrogen, form one atom of water, an essentially indifferent body.
Azote, Phosphorus, Arsenic.	Half an atom of each of these, and one atom and a half of hydrogen, form one atom of a gaseous basic body.
Carbon.	2 atoms of this body and 2 atoms of hydrogen, form 1 atom of a gaseous basic body.”—Dumas, *Traité de Chimie*, 1828, t. i. p. lxxv.

In Monk Lewis's “ *Tales of Terror*,” is a story of a Fire-King, who stole a young lady, and, to gain favour with her, pledged himself to obey her three first commands.—“ Show me,” she said, “ the *truest* of lovers.” 'Twas done. “ Now show me a *truer*.”

I assure you, upon the veracity of Monk Lewis, that the Fire-King was discomfited, and unable to obey the order. This is the only instance upon record of a damsel's triumph over a spiritual foe, in consequence of her understanding the grammatical principles of the *comparison of adjectives*.

But had the lady been in the power of the French Chemist, instead of the Runic Fire-King, things might have gone much worse with her. The man who can produce a *smaller* atom than the *smallest*, could have had no difficulty in providing a *truer* lover than the *truest*.

When will the age of conjurers be passed!

Atomic Weight.—*The weight of an atom of a substance.*

Conceive the division of a mass of potassium till you come to a single atom, and represent the weight of this atom by any number you please, say 1, 10, 100, 1000, or any other number taken arbitrarily.

Conceive the separation, in like manner, of a single atom of lead, hydrogen, carbon, chlorine, sulphur, and oxygen.

The numbers which represent the *weights of the atoms* of these seven substances, must bear the following relations to each other:—

Potassium,....................	10
Lead,........................	26
Hydrogen,....................	0¼
Carbon,......................	3
Chlorine,....................	9
Sulphur,.....................	4
Oxygen,......................	4

The relative weights of the atoms of the elements are very different from each other, and remain very different by whatever exponents they are denoted. In fixing upon a series of numbers to represent the atomic weights, the reasonable principle of choice is, to fix upon the simplest.

The atomic weights of all the elements are exhibited in the Table of Elements, page 195.

Combination takes place between the atoms of the elements. Their atomic weights represent the weights of their combining proportions. And, *per contra*, a knowledge of their combining proportions leads to a knowledge of their atomic weights.

I fixed upon 4 as the representative of oxygen, because I found it upon trial to be a most *convenient* number, and I consider that, in making a scale of numbers to represent the ratios in which bodies combine, *convenience* is a thing which well deserves to be attended to. The simpler the figures, the more easy are the calculations; and the more easy the calculations, the more accurate the products. Tedious calculations weary the operator and induce errors. Great philosophers, quietly luxuriating in their college retirements, may, if they please, carry out their fractional calculations to the utmost extent of mathematical refinement; but men of business have no time to spend on unphilosophical niceties, and if the atomic theory and the atomic weights are to be made applicable to purposes of learning and purposes of commerce, *they must be simplified.*

Atomic Weight of a Compound.—*The sum of the conjoint atomic weights of its two constituents.*

Volume.—*The smallest possible measure of a gas.*

Atomic Measure.—*The volume or volumes occupied by an atom of a gaseous substance.*

The *atomic measure of an elementary gas* is one volume.

The *atomic measure of a compound gas,* is the volume or volumes produced by the combination of its elements.

The atomic measure of a gas, elementary or compound, represents its combining proportion.

The specific gravity of an elementary gas is equal to its atomic weight.

The specific gravity of a compound gas depends upon its atomic measure.

If, of the atomic weight, the atomic measure, and the specific gravity of a gas, we know two terms, it is easy to find the third:—

$a.\ m.$ = atomic measure,
$a.\ w.$ = atomic weight,
$sp.\ gr.$ = specific gravity.

To find the specific gravity of a gas. $\frac{a.\ w.}{a.\ m.} = sp.\ gr.$
Divide the atomic weight by the atomic measure, the quotient is the specific gravity.

To find the atomic weight of a gas. $a.\ w. = a.\ m. \times sp.\ gr.$
Multiply the atomic measure by the specific gravity, the quotient is the atomic weight.

To find the atomic measure of a gas. $\frac{a.\ w.}{sp.\ gr.} = a.\ m.$
Divide the atomic weight by the specific gravity, the quotient is the atomic measure.

Symbol of an Atom.—*A letter or pair of letters which denote an elementary atom.*

Thus K signifies an atom or 10 parts of potassium, Cl signifies an atom or 9 parts of chlorine, O signifies an atom or 4 parts of oxygen.

See the symbols of the atoms of all the elements in the TABLE OF ELEMENTS, page 195.

NAME OF AN ATOM.—*A word of two syllables, equivalent in meaning to the symbol of an atom. It denotes an atom of the element it designates.*

Thus KALI signifies 10 parts of potassium, CHLORI signifies 9 parts of chlorine, OXI signifies 4 parts of oxygen.

See the names of the atoms of all the elements in the TABLE OF ELEMENTS, page 195.

POSITIVE AND NEGATIVE.—*Words which denote a tendency to combination between the substances they are respectively applied to.*

Every element in the TABLE OF ELEMENTS, page 195, is POSITIVE towards all that are placed below it, and NEGATIVE towards all that are placed above it.

A COMPOUND OF TWO ELEMENTS is POSITIVE towards an uncombined atom of the *negative* element of the compound, and NEGATIVE towards an uncombined atom of the *positive* element of the compound. It is also *negative* towards another compound of the same two elements, having the positive element in greater excess, and *positive* towards another compound of the same two elements, having the negative element in greater excess.

The natural power in virtue of which the atoms of elements combine and produce compounds, is unknown to us except by the manifestation of its effects. We find by experiment that the elements *combine*, but we cannot discover what it is that *makes them* combine.

When chemical compounds are strongly electrified, they suffer decomposition, and the liberated atoms of their constituents appear partly at the positive pole and partly at the negative pole of the electric apparatus. Those which appear at the positive pole are denominated *electro-negative* elements, and those which appear at the other pole, *electro-positive* elements. It is found that every element is *negative* towards a portion of the elements, and *positive* towards the rest. The elements in the list at page 195 are so arranged that the one having the strongest electro-positive energies begins it, and that possessing the most powerful electro-negative energies ends it. The intermediate elements are electro-negative in relation to those which precede them, and electro-positive in relation to those which follow.

The manifestation of electrical appearances at the moment when an act of combination or decomposition is effected, throws no light upon the nature of the force which makes the elements combine. We see nothing more than the phenomena by which the acts of combination and decomposition are attended.

When a number of chemical elements are set at liberty in juxtaposition, those combinations take place, which produce such compounds as can best exist *under the circumstances* in which the occurrence is brought to pass. The same elements brought together at a *low* temperature, at a *medium* temperature, and at a *high* temperature, produce different compounds, i. e. they produce such compounds as can best exist *under the circumstances* of the trial.

If a compound, consisting of a powerful electro-negative element and of an indifferent element, i. e. of one possessing no very marked electrical powers, be brought into contact with a powerful electro-positive element, decomposition is immediately effected, and those two elements which exhibit the antagonistic electricities most strikingly, combine to the exclusion of the other. The VERY NEUTRAL compound produced by the combination of an *electro-positive* with an *electro-negative* element, can better exist in presence of an *indifferent* element, than the SEMI-NEUTRAL compound composed of an *indifferent* in combination with an *electro-negative*, can exist in presence of an *electro-positive*. In the one case, the electrical power is partially at rest; in the other, its dispersive influence is in full operation.

When compounds are placed in juxtaposition, in a state fitted for chemical action, as, for example, in solution in water, they are observed to *decompose each other*, PROVIDED that, by doing so, they can give origin to other compounds more capable than the original compounds of emerging from the sphere of each other's action; OTHERWISE, they *do not decompose each other*. If, for example, we put together two soluble salts, of such a nature as to give rise, by an interchange of their antagonistic electrical elements, to two other salts of the same degree of solubility, then no decomposition takes place. But if, on the other hand, we place together two salts of such a nature, that the interchange of their antagonistic electrical elements can produce two salts, both or one of less solubility than the original salts, then decomposition is effected,—let the insolubility of the new salt result from its tendency to assume either the solid form or the gaseous.

Hence we draw a rule useful in practice:—*Two saline compounds in solution being given, if the electro-negative element of the one can produce, with the electro-positive element of the other, a compound insoluble in the water of the given solutions, then, upon mixing the solutions, precipitation or gaseous ascension will occur.*

For example, the compound called sulphate of barytes is insoluble in aqueous solutions of the sulphates and chlorides. If, therefore, we mix a solution of chloride of barium with a solution of sulphate of soda, the sulphur and oxygen of the latter combine with the barium of the former, and precipitate in the state of sulphate of barytes—leaving chloride of sodium in the supernatant solution.

When we act upon unknown compounds and produce known compounds, we are certain that the ultimate elements of the known compounds were present in the unknown compounds; but we remain totally uncertain whether the known compounds *existed ready-formed* in the unknown compounds, or *were produced* at the instant when the ultimate elements of the unknown compounds were set at freedom by decomposition; consequently, we can only assume with safety, that the unknown compounds contained the ultimate elements of the known compounds. We cannot admit that the known compounds formed the proximate constituents of the unknown compounds, because we have no proof of it.

A mixture of borate of soda and sulphuric acid produces, *at a red heat*, borate of soda and sulphuric acid; but at the *heat of boiling water*, and in solution, it produces sulphate of soda and boracic acid. In the first case, the sulphuric acid separates by volatilisation; in the second case, the boracic acid separates by precipitation. Thus the proximate constituents afforded by the decomposition of compounds are different under different circumstances of decomposition. If the two original compounds, and the two compounds capable of being produced by the interchange of their antagonistic electrical elements, were all equally fixed in the fire, and equally soluble in water, there would be no decomposition at all.

Vain, therefore, is the attempt to effect double decomposition, excepting where it can produce new compounds, self-empowered to get readily out of each other's vicinity.

Having giving these facts regarding the circumstances attending decompositions, and having stated my ignorance of the nature of the power which causes combination, I may add, that I find in chemical books a pretended explanation of all those particulars, under the sanction of certain occult powers denominated *elective affinity*, *double elective affinity*, *divellent affinity, quiescent affinity*, &c.; of all which I will only say, that they give me not a single idea. The *reasoning* in which these terms are employed appears to me a mere play upon words, and I would recommend the term *affinity* to be entirely discarded.

THEORY OF COMBINATION.

P = atom of a positive element.
N = atom of a negative element.

Rule I.—Every compound is formed by the combination of one atom of each of its constituents, be they elementary or compound.

This rule includes the principle of all that follow.

Rule II.—One P combines with one N, and constitutes PN.

Rule III.—A compound PN can combine either with one P to produce PPN, or with one N to produce PNN.

Rule IV.—Any compound of one P with more than one N, can combine with another N. And any compound of one N with more than one P, can combine with another P.

Rule V.—A compound containing any number of atoms of P and N, can combine with that compound of P and N which is likest to it in composition, and produce an intermediate compound.

Rule VI.—An atom of any compound can combine with an atom of any element, or with an atom of any other compound.

LIMITS OF COMBINATION.

The admirers of the terms PRO and PER seem to have a notion that they are acquainted with the limits of combination. They find two compounds comprising the same elements in different proportions. They fix upon one of them as that which contains the greatest possible quantity of the positive element, and upon the other as that which contains the greatest possible quantity of the negative element. And thereupon they delay not to fix, with *pros* and *pers*, and *maximums* and *minimums*, the two doomed compounds in their ordained places; never imagining that in the still-unexplored regions of nature, other compounds may exist, much better entitled than the two discovered compounds to the *pros* and the *pers*, and all the other signs of distinction.

It is strange that any man should determine dogmatically what *does* and what *does not* exist, or what *can* and what *cannot*, as if he had gauged the universe with the rule of its Creator. There is no end to philosophical vanity.

The limits of combination form a bad ground-work for a nomenclature, for they are undiscoverable points. Every attempt to fix them has proved nugatory. One could, indeed, almost prove the impossibility of discovering them.

One atom of P combines with an atom of N, and produces the compound PN. What the cause of the combination may be, I know not. Call it *affinity*, call it *electricity*, call it by any name you please, I care not. Of one thing only am I sure, and that is, that the elements *do combine*.

But without knowing the nature of the combining power, we can mark its workings; and we learn by so doing, not only that it makes the elements combine, but endows the resulting compounds with the power of entering into other compounds. Thus the compound PN can combine with P, and produce PPN, or with N, and produce PNN. That is to say, the compound PN, immediately upon its production, assumes such properties that it becomes *negative* towards the element P, and *positive* towards the element N. This opinion is the basis of the rules I have presented under the head of "theory of combination," and I believe that the principle it involves is the one best adapted to guide us through the wilds of chemical intricacy.

Let us see to what this theory leads us.

If PPN can combine with P to produce PPPN, and PPPN with P to produce PPPPN, then, by following up this series of compounds, we may, according to RULE IV., carry out the series to a prodigious extent. If a compound of P with N is always negative towards P, and positive towards N, there is no conceivable limit to combination in this direction. We can imagine the existence of a series of compounds commencing with $1 P + 1 N$, and proceeding to $100 P + 1 N$, or even to $1000 P + 1 N$.

And on the other hand, as things which are equal to the same thing are equal to each other, and as the power of combination must be as active in negative as in positive elements, we can imagine the formation of a negative series, commencing also with $1 P + 1 N$, and proceeding to $100 N + 1 P$, or $1000 N + 1 P$.

And even when we proceed to these extreme points, we perceive no indications of the limit of combination. The principle once granted that PN can combine with N, and PNN with N, it cannot afterwards be safely denied that $P^1 + N^{1000}$ is capable of combining with 1 more N. The force which produces combination may indeed be exerted very feebly in such a case, but still *it may be exerted*, and no man can safely put his finger upon any place in a table such as the following, and say, "here *is the* MAXIMUM *and here the* MINIMUM *compound*."*

---

* The greater part of this SECTION of "Chemical Recreations" was written in the year 1830, and explained to two chemical friends of mine, who disapproved both of the nomenclature and of the theoretic views upon which it is founded, treating them both, perhaps justly, as belonging only to the *Romance* of chemistry. This condemnation was one cause of my not publishing the nomenclature sooner, and possibly ought to determine me not to publish it now. Nevertheless, five years of consideration have left my vanity in the conviction that what I have written may yield some amusement if it afford no instruction, and that, separated from all practical subjects, its publication can do but little harm, even if it fail to do much good. I venture, therefore, to print it, not as the *Philosophy*, but as the *Romance of Chemistry*, hoping that, in this guise, it may pass muster among other varieties of "Chemical Recreations."

Possibly the reader may rank among the causes which finally influence me to publish this essay, the reading of a letter of JOHN DALTON's, published at the end of DAUBENY's *Introduction to the Atomic Theory*, and which came under my notice in the year 1832. This letter exhibits DALTON as admitting the existence of compounds formed like those typified by the 5 central terms of the series exhibited by the above table; while, at the same time, he rejects the notion of the formation of compounds by the combination of 1, 2, 3, 4, 5, &c. atoms of one

p = 1 positive atom.	n = 1 negative atom.	Total.	
		p	n
pppppppppppp	n	12	1
ppppppppppp	n	11	1
pppppppppp	n	10	1
ppppppppp	n	9	1
pppppppp	n	8	1
ppppppp	n	7	1
pppppp	n	6	1
ppppp	n	5	1
pppp	n	4	1
ppp	n	3	1
pp	n	2	1
p	n	1	1
p	nn	1	2
p	nnn	1	3
p	nnnn	1	4
p	nnnnn	1	5
p	nnnnnn	1	6
p	nnnnnnn	1	7
p	nnnnnnnn	1	8
p	nnnnnnnnn	1	9
p	nnnnnnnnnn	1	10
p	nnnnnnnnnnn	1	11
p	nnnnnnnnnnnn	1	12

compound with one atom of another. I do not know whether this important admission of DALTON's has yet been commented on by any other chemist. The following is an extract from his letter:—

"Suppose I find that in two elements, A and B, there are the following combinations, namely:—

Grains.		Grains.
A 2	+	B 2
A 2	+	B 3
A 2	+	B 6
A 2	+	B 12
A 2	+	B 18

and that these 5 are all the combinations I can find experimentally. Now, should I be so unlucky as to take the first for a binary compound, and consider the atoms of A and B as of equal weights, I should be puzzled to account for the rest of the combinations: the 2nd would be 3 atoms of B with 2 of A; the 3rd would be 1 atom of A with 3 of B; the 4th, 1 atom of A with 6 of B; and the 5th, 1 atom of A with 9 of B. But I might ask, why should they not be combinations of the intermediate numbers?

If these notions are compared with the evidence afforded by experiment, it will be perceived that the number of compounds hitherto discovered is infinitely smaller than might have been expected. Instead of a series extending from 100 P + 1 N to 1 P + 1 N, and 1 P + 100 N, we seldom find compounds extending beyond the limits of the series :—

PPPP N
PPP N
PP N
P N
P NN
P NNN
P NNNN

while, indeed, the greater part of the well-known compounds of two elements are comprised between the limits PPN and PNN. But how many hitherto-undiscovered compounds may in time to come appear and swell the list, no man can tell.

Leopold Gmelin, a chemist of great learning, who examined this subject with much attention, states, that "Chemical compounds, collectively considered, are constituted in such a manner that one atom of the one element may be considered to be combined with one-sixth, one-fourth, one-third, one-half, two-thirds, three-fourths, one, one and one-third, one and one-half, two, two and one-half, three, four, five, six, seven, or more atoms of the other element."—*Handbuch der Theoretischen Chemie*, I., 32.

These fractions give us the following series.

	P	N		P	N		
a	1	$\frac{1}{6}$	equivalent to	6	1	=	PPPPPPN
b	1	$\frac{1}{4}$	=	4	1	=	PPPPN
c	1	$\frac{1}{3}$	=	3	1	=	PPPN
d	1	$\frac{1}{2}$	=	2	1	=	PPN
e	1	$\frac{2}{3}$	=	3	2	=	PPN, PN
f	1	$\frac{3}{4}$	=	4	3	=	PN,PPN,PN
g	1	1	=	1	1	=	PN
h	1	$1\frac{1}{3}$	=	3	4	=	PN, PN, PNN
i	1	$1\frac{1}{2}$	=	2	3	=	PN, PNN
k	1	2	=	1	2	=	PNN
l	1	$2\frac{1}{2}$	=	2	5	=	PNN, PNNN
m	1	3	=	1	3	=	PNNN
n	1	4	=	1	4	=	PNNNN
o	1	5	=	1	5	=	PNNNNN
p	1	6	=	1	6	=	PNNNNNN
q	1	7	=	1	7	=	PNNNNNNN
r	1	8	=	1	8	=	PNNNNNNNN

" A much more probable supposition would be, to take as the

Of these compounds, it will be seen that a, b, c, d, g, k, m, n, o, p, q, r, form part of theoretic series in the foregoing table (page 207), while e, f, h, i, l, are not to be found there. Yet, as these compounds exist in nature, the theory should afford them a place. Let us endeavour to provide one.

I have admitted that a compound PN combines with P or with N, in consequence of being in an opposite electrical state; that is to say, being more negative than P and more positive than N, or, in other words, that PN combines either with P or N, *because it does combine*, for that is the best explanation I can give. And in saying this, I may remark that the fashionable phrase of *because they have an affinity for each other*, means exactly, *because they combine*, which shows clearly enough, that affinity is only a figure of speech.

Upon the self-same principles, I admit that the tendency to combination exists between the compound PN and either the more positive compound PPN, or the more negative compound PNN; which combinations necessarily produce the two compounds— PPP NN

PP NNN

the equivalents of *e* and *i* in the series furnished by GMELIN.

In the same manner, by admitting the *inter-combination* of compounds with each other, as expressed under POSITIVE and NEGATIVE, page 201, and THEORY OF COMBINATION, page 204, RULE V., we produce a series of compounds which not only differ entirely in the relative proportions of their constituents from any of the compounds resulting from the successive additions of atoms of P or N to PN, but which we may conceive as being so extended as to afford, in conjunction with the direct theoretic series formerly adduced, the idea of unlimited combination.

By following out this theory to only a very small extent, we produce the series of intermediate compounds exhibited in the following table, in which every compound of GMELIN'S list, not previously pointed out by the theory here advocated, will be found in its proper place.

---

atomic weights, A 2 and B 6; then the 3d would be a binary combination; the 2nd and 4th ternary; and the 1st and 5th quaternary; so that there would be no occasion to have more than 4 atoms in any group, and we should have no deficiencies in the combination."

The reader will perceive, that in the sea of this romantic theory DALTON and myself are sailing in the same craft.

p = 1 positive atom.	n = 1 negative atom.	Total.	
		p	n
PPPPP	N	5	1
ppppppppp	nn	9	2
PPPP	N	4	1
ppppppp	nn	7	2
PPP	N	3	1
pppppppp	nnn	8	3
ppppp	nn	5	2
ppppppp	nnn	7	3
PP	N	2	1
ppppp	nnn	5	3
ppp	nn	3	2
pppp	nnn	4	3
P	N	1	1
ppp	nnnn	3	4
pp	nnn	2	3
ppp	nnnnn	3	5
P	NN	1	2
ppp	nnnnnnn	3	7
pp	nnnnn	2	5
ppp	nnnnnnnn	3	8
P	NNN	1	3
pp	nnnnnnn	2	7
P	NNNN	1	4
pp	nnnnnnnnn	2	9
P	NNNNN	1	5

However extensive these theoretic views may be, they cannot readily lead to confusion. Keeping always in idea that the compound P N is composed of one atom of each of its elements, every other compound of P and N, either in the positive or negative series, must consist of an atom of P and an atom of N, each multiplied by a whole number. Thus:—

$$\text{PPN is equal to } \begin{cases} 1\ \text{P} \times 2 = 2\ \text{P} \\ 1\ \text{N} \times 1 = 1\ \text{N} \end{cases}$$

$$\text{PNNN is equal to } \begin{cases} 1\ \text{P} \times 1 = 1\ \text{P} \\ 1\ \text{N} \times 3 = 3\ \text{N} \end{cases}$$

$$\text{and PPPNN is equal to } \begin{cases} 1\ \text{P} \times 3 = 3\ \text{P} \\ 1\ \text{N} \times 2 = 2\ \text{N} \end{cases}$$

TABLE SHOWING THE TOTAL NUMBER OF ATOMS OF P AND N *contained in the compounds exhibited in the* TABLES *at pages 207 and 210.*

p = 1 positive atom.	n = 1 negative atom.	Total.	
		p	n
pppppppppppp	n	12	1
ppppppppppp	n	11	1
pppppppppp	n	10	1
ppppppppp	n	9	1
pppppppp	n	8	1
ppppppp	n	7	1
pppppp	n	6	1
ppppp	n	5	1
ppppppppp	nn	9	2
pppp	n	4	1
ppppppp	nn	7	2
ppp	n	3	1
pppppppp	nnn	8	3
ppppp	nn	5	2
ppppppp	nnn	7	3
pp	n	2	1
ppppp	nnn	5	3
ppp	nn	3	2
pppp	nnn	4	3
ppppp	nnnn	5	4
p	n	1	1
pppp	nnnnn	4	5
ppp	nnnn	3	4
pp	nnn	2	3
ppp	nnnnn	3	5
p	nn	1	2
ppp	nnnnnnn	3	7
pp	nnnnn	2	5
ppp	nnnnnnnn	3	8
p	nnn	1	3
pp	nnnnnnn	2	7
p	nnnn	1	4
pp	nnnnnnnnn	2	9
p	nnnnn	1	5
p	nnnnnn	1	6
p	nnnnnnn	1	7
p	nnnnnnnn	1	8
p	nnnnnnnnn	1	9
p	nnnnnnnnnn	1	10
p	nnnnnnnnnnn	1	11
p	nnnnnnnnnnnn	1	12

Having shown the manner in which we arrive at a knowledge of the atomic constitution of the possible compounds of any two elements, I proceed in the next place to illustrate the formation of compounds containing three, four, or any greater number of elements.

I admit (THEORY OF COMBINATION, RULE VI.) that "an atom of any compound can combine with an atom of any element, or with an atom of any other compound." This admission grants the possible existence of compounds containing any number of elements in any number of atoms. It is a principle wide enough to embrace all possible cases.

But when we compare known compounds with the immense series of which we thus imagine the existence, we find that both the number of elements and the number of atoms they contain is exceedingly few in comparison with what we may conceive to be possible. Nine-tenths of all the chemical compounds known to exist, contain but TWO or THREE *different elements.* A few contain *four* and *five* elements, while the number of those which contain *six* and upwards is exceedingly small. And it is the same with respect to the *number of atoms:* 1, 2, 3, and 4 atoms of any one element are the numbers which we most generally find, and though we also meet with 5, 6, 7, 8, 9, 10, and 12, it is only in cases of much rarer occurrence; whilst higher numbers than these are almost unknown.

Yet, with a vast mass of experimental evidence to enlighten us, we cannot perceive the slightest trace of any limit to combination, even in this direction; and though, in practice, our attention falls exclusively upon compounds containing but few elements and few atoms, we must in theory, admit, as I have before stated, the existence of compounds containing any number of elements in any number of atoms. If we do this, we have a theory that can take in any compound which may be hereafter produced, whereas, if we do not, we may possibly discover *to-morrow* a compound of such a constitution that our theory will not be prepared to give any account of it, to afford any place for it, or apply any name to it.

The objection, that it is useless to imagine the existence of compounds that do not exist, falls to the ground, unless the objector can *prove the non-existence* of the imagined compounds. A theory which is to stand the test of time must embrace not merely the compounds now known, but be qualified to give "a local habitation and a name" to all those which may hereafter be discovered.

It is impossible to give complete tables of the atomic constitution of the substances producible by the combination of compounds with compounds or elements. They could be extended immeasurably and still be incomplete. I shall restrict myself to giving a few small tables of the atomic constitution of the compounds now found to be of most frequent occurrence.

Let a, b, c, x, y, z, represent atoms arranged in the order of their combining powers, *a* being the extreme positive and *z* the extreme negative.

My views of the combining powers of compounds are given at page 201, § 3 of the definition of "Positive and Negative."

Compounds produced by ab and z.

	Total	a	b	z
ab ab ab ab z	=	4	4	1
ab ab ab z	=	3	3	1
ab ab z	=	2	2	1
ab z	=	1	1	1
ab z z	=	1	1	2
ab z z z	=	1	1	3
ab z z z z	=	1	1	4

Compounds produced by a and yz

	Total	a	y	z
a a a yz	=	3	1	1
a a yz	=	2	1	1
a yz	=	1	1	1
a yz yz	=	1	2	2
a yz yz yz	=	1	3	3

Compounds produced by az and yz

	Total	a	y	z
az az az yz	=	3	1	4
az az yz	=	2	1	3
az yz	=	1	1	2
az yz yz	=	1	2	3
az yz yz yz	=	1	3	4

COMPOUNDS PRODUCED BY ayz AND byz

	Total	a	b	y	z
ayz ayz byz	=	2	1	3	3
ayz byz	=	1	1	2	2
ayz byz byz	=	1	2	3	3

Upon calculating the atomic constitution of 400 well known compounds, I found that 214 containing two elements each, were comprised in the table at page 211, 153 containing 3 and 4 elements each were embraced in the 4 small tables just presented, and 31 containing 3 and 4 elements and 2 containing 5 elements were of too complicated a constitution to be denoted except by express formulæ.

APPLICATION OF THIS THEORY.

In attempting to explain the production of compounds from elements, I have throughout considered the atomic weight of P and N as things known and determined; but it will be evident to the most superficial observer, that no application of this theory can be made to chemistry in its present state, unless we determine the atomic weights of every element registered in the table at page 195. This table, indeed, exhibits what I consider to be the atomic weights of the elements, but it presents no evidence to prove that these weights are correctly assumed. Yet the accuracy of the data from which these weights are deduced is a point of the very first importance.

It is easy to form a table such as the following, and to say that the middle term is that which contains a single atom of each element.

P P N
P N
P N N

But, when we are presented by nature with three compounds containing the same two elements combined in different proportions, we find it a problem often very difficult of solution to determine which of these compounds is that containing but one atom of each element.

For example, in the case of the three compounds of oxygen and nitrogen, experiment proves the relative weights of the two elements to be in the three compounds as follows:—

	Nitrog.		Oxygen.		Nitrog.		Oxyg.
1. Nitrous oxide	1	+	0·571	or	7	+	4
2. Nitric oxide	1	+	1·143	—	3·5	+	4
3. Nitrous acid	1	+	2·286	—	3·5	+	8

Now, according as we suppose the *first*, the *second*, or the *third* of these compounds to be that which is composed of a single atom of each element, we obtain a series of numbers wholly different from those obtained on the contrary suppositions.

	1	2	3
Nitrous oxide	1 N + 1 O	2 N + 1 O	4 N + 1 O
Nitric oxide	1 N + 2 O	1 N + 1 O	2 N + 1 O
Nitrous acid	1 N + 4 O	1 N + 2 O	1 N + 1 O

and each of these sets gives a different number to represent the weight of the atom of nitrogen or oxygen.

	after 1.	after 2.	after 3.
Oxygen...........................	4	4	8
Nitrogen	7	3·5	3·5

Hence it is of prodigious importance to find some method of discriminating with certainty a single atom of an element from any multipled atom.

Let us examine the principles upon which chemists are accustomed to discriminate between single and multipled atoms.

METHOD OF DUMAS.

In stating the composition of three metallic oxides, and specifying the difficulty of determining which of them is the one containing a single atom of each constituent, he says,—

"It would be very difficult, perhaps impossible, to choose among these three series, if we were guided solely by motives of complete evidence. Wherefore, to settle the question once for all, and to cut short the difficulties which occur incessantly, as nearly all the metals are in the same case, chemists have agreed to follow a rule, purely arbitrary indeed, but sufficient for their actual wants. It consists in giving the preference to the proportional number derived from the protoxide.

"*The proportional number, or the proportion of a body, is, therefore, the quantity in weight of that body which, by combining with that quantity of oxygen which has been taken arbitrarily for* its *atom, gives rise to the first oxide.*"

By the help of this formula, Dumas determines the proportional numbers of all the simple bodies excepting the following:

Oxygen
Boron
Chlorine
Bromine
Iodine
Fluorine
Phosphorus
Selenium
Silicium
Antimony
Arsenic
Chromium
Tantalum
Titanium
Tungsten.

Of these he remarks, that "they form acid compounds evidently containing many atoms of oxygen, while they do not present us with protoxides; so that it is necessary to adopt a different method to determine the proportional number of these elements.

"We have, therefore," says he, "taken, for its proportional number, that quantity of the body which is contained in a quantity of its acid capable of saturating a quantity of oxide containing one proportion of oxygen."—*Traité de Chimie*, t. i., p. xxxiii.

This system of DUMAS's is founded upon a presumed acquaintance with the limits of combination. Using his method strictly, we could not find a single atomic weight without first learning the maximum quantity of a metal which can combine with a given quantity of oxygen. But as this maximum quantity is a thing impossible to determine, it follows that every atomic weight deduced from a pretended acquaintance with it, must be neither more nor less than the product of a *guess* made entirely at random.

METHOD OF DR THOMAS THOMSON.

Considerations by which, as he informs us, he was led to fix upon his atomic numbers. *First Principles of Chemistry*, vol. i. p. 44.

I. "Neutral salts (that is, salts which are neither acid nor alcaline) are *probably* composed of 1 atom of acid united to 1 atom of base. When the salt has acid qualities, it is *probably* a compound of 1 atom base and more than 1 atom of acid. When it possesses alcaline qualities, it is *probably* a compound of 1 atom acid and more than 1 atom of base; but *to these rules there are many exceptions.*

II. "The weights of certain acidifiable bases were determined by their relation to oxygen. Thus it was found that 2 of sulphur is capable of combining with 1, 2, and 3 of oxygen. Hence it was concluded that 2 represents the atomic weight of sulphur.—In like manner, 0·75 carbon unites with 1 and 2 of oxygen. Hence 0·75 represents an atom of carbon.—1·75 azote combines with 1, 2, 3, 4, 5 of oxygen. Hence," &c.

The first set of these considerations is founded upon *three probabilities liable to many exceptions*, most certainly a very unfit foundation whereon to "establish the first principles of chemistry." If, indeed, there were even no exceptions to the given rules, and if the probability was certainty, we are still left with but vague ideas of what is meant by the terms neutral salts, atoms of acid, and atoms of base. A speculator may twist these phrases to any meaning he pleases to invest them with.

The second consideration is founded upon the assumption that 1 of oxygen cannot combine with more than 2 of sulphur, 0·75 of carbon, and 1·75 of nitrogen. A system built upon such a basis, if good for the day in which it was built, is wholly unfit for after-time. Serving to represent merely the knowledge of the writer, and wholly destitute of general principles, it must necessarily be incapable of representing a more advanced state of the science. Atomic numbers thus deduced are daily exposed to the necessity of change. In the case of sulphur, for example, the number which is here stated to represent its atom will become entirely inadequate to the purpose, as soon as a compound shall be produced containing 1 of oxygen combined with 3, 4, or any greater quantity of sulphur. And who can say that such a compound will not be produced? who can pretend to fix the limits of combination in any case, to determine which is the minimum or maximum proportion of any element, or to say to nature, "thus far shalt thou go, and no farther?"

I grant that no man can express more than he knows, and I will add, that no man ought to express more than he knows. A chemical theory should represent the truth, the whole truth, but nothing beyond the truth. A science of experiment requires that its facts should be classified and its productions named, and it requires but little more than this.

Not to dispose of Dr THOMSON's method too briefly, it may be worth while to follow him a little way among the details of his system. Speaking of the combinations of oxygen and hydrogen, he says,

(1.) "It is a well known fact that these two gases cannot be directly united in any other proportions than those which exist in water.—(2.) It is of *no great consequence* which of these two opinions (*i. e.* whether the atom of hydrogen be one volume or two volumes) be adopted; yet if we take a view of the various compounds into which hydrogen enters, we can have little hesitation in fixing upon 0·125 (oxygen being = 1·0) for its atomic weight.—(3.) Would it not be a singular anomaly, if water, which is decomposed with considerable difficulty, should consist of one atom of oxygen united to two atoms of hydrogen, while the deutoxide, which parts with half its oxygen very readily, consists of one atom of oxygen united to one atom of hydrogen?—(4.) Hydrogen never unites with azote, carbon, phosphorus, and sulphur, in a smaller proportion than 0·125. Now, it would be a most extraordinary phenomenon, if never less than two atoms of this substance were to unite with an atom of other bodies. If 0·0625 is the atomic weight of hydrogen, how comes it that it never unites to any of these bodies in so small a quantity?"—*First Principles*, I. 73—76.

The well known "fact" (1.) cannot be proved. If two volumes each of oxygen and hydrogen are detonated together, only one volume of oxygen remains. It is nevertheless *possible* that the four gaseous volumes are first converted into the deutoxide, and that the deutoxide is subsequently converted (by the heat engendered in the process) into water and oxygen. We can *imagine* the production of water to be owing to the strong tendency of the deutoxide of hydrogen to combine with hydrogen at a high temperature.—(2.) I think, on the contrary, that it is of the *greatest consequence* which of these two opinions be adopted. THOMSON does not appear to have considered to what the opinion he opposed was capable of leading.—(3.) THOMSON imagines that a pinch of common salt thrown into a glass of water instantaneously decomposes a certain quantity of the water. Is this to be considered a proof that "water is decomposed with considerable difficulty?" Particular views respecting the facility or difficulty with which a compound can be decomposed, can never give any clue to the number of atoms contained in the compound.—(4.) What is here stated is not correct in point of fact. It can be proven that every one of the substances which THOMSON quotes, occurs in compounds which contain only one volume of hydrogen. For example, in prussic acid, oxalic acid, oil of vitriol, and hydrate of phosphoric acid. He acknowledges himself, only a few pages farther on in his book, that one volume of azote combines with three volumes of hydrogen, to produce ammonia. His reasoning is reasoning in a circle. He is eternally running round after truth without catching it, and reminds one of a kitten pursuing its tail. He fixes hydrogen at two volumes, and is then *obliged* to fix azote at two also, to enable him to explain the composition of ammonia. Having done this, he turns round, and says, " since the atom of azote is two volumes, the atom of hydrogen must be two volumes." I reply, since the atom of azote is one volume, the atom of hydrogen must be one volume. I shall pursue the subject no farther, particularly as THOMSON thinks it of " no great consequence."

METHOD OF DR EDWARD TURNER.

" As no compound of oxygen and hydrogen is known which has a less proportion of oxygen than water, it is *supposed* to contain one atom of each of its constituents. This view of the atomic constitution of water appears to be justified by the *strong affinity* which its elements evince for one another, as well as from the proportions with which they respectively combine with other bodies."—*Elements of Chemistry*, p. 194.

It is unnecessary to reply to a mere *supposition*, which has neither evidence nor argument in support of it, and which is grounded on a presumed acquaintance with the limits of combination. As to *affinity*, I consider it a chimera.

METHOD OF LEOPOLD GMELIN.

" It is found by experiment that 100 parts of water consist of 11·1 hydrogen, and 88·9 oxygen. *If* we consider the atomic weight of hydrogen to be unity, and *imagine* that water contains one atom of hydrogen combined with one atom of oxygen, then 11·1 : 88·9 : : 1 : 8, and the atomic weight of oxygen is 8. But whether water contains one atom of hydrogen combined with one atom of oxygen, or one atom of hydrogen with two atoms of oxygen, or two atoms of hydrogen with one atom of oxygen, is a point which cannot be decided with certainty. The first view, however, is the most probable, though BERZELIUS and DAVY have decided in favour of the last. It is possible, with respect to many other compounds, to adopt a variety of different atomic weights. This is *really perplexing*."—*Handbuch der Theoretischen Chemie*, book I., p. 33.

There is, as GMELIN has justly observed, no method of deciding with certainty whether water contains one atom or two atoms of hydrogen; but, on the other hand, there is a method of escaping from all *perplexity* on the subject, at least with relation to this as well as to a great many other substances. This is by following the principle adopted by BERZELIUS and DAVY, that the atom of every gaseous element is represented by its volume. I hope to convince the reader that the observation of this principle is sufficient to guide us through some of the most puzzling mazes of chemical theory.

METHOD OF JOHN DALTON.

"1. When only one combination of two bodies can be obtained, it must be presumed to be a *binary* one, unless some cause appear to the contrary. 2. When two combinations are observed, they must be presumed to be a *binary* and a *ternary*. 3. When three combinations are obtained, we may expect one to be a *binary*, and the other two *ternary*. 4. When four combinations are observed, we should expect one to be *binary*, two *ternary*, and one *quaternary*, &c. 5. A binary compound should be always specifically heavier than the mere mixture of its two ingredients."—Quoted from THOMSON'S *First Principles*, v. I., p. 38.

To one and all of these rules I say WHY? Dr THOMSON declares that the first four, perhaps with the exception of the third, are "unexceptionable." I ask again *why?*

How did DALTON learn that Nature made it a practice, never departed from in the case of the compounds of any two elements, to let the *first discovery* be invariably a binary compound; the *second discovery*, a ternary compound; the *third discovery*, a ternary compound; and the *fourth discovery*, a quaternary compound?

Is it a matter of fact that compounds are discovered in this precise order? If not, DALTON'S rules militate against experience.

Examine the first set of chemical tables you lay your hands upon, and compare them with Dalton's rules. Alas, for the "unexceptionables!"

Look at the constitution of ammonia: 3 volumes of hydrogen and 1 volume of nitrogen. "Behold," says DALTON, "a *binary* compound!" And Dalton's rule is "unexceptionable!"

Examine the compounds of oxygen and hydrogen. The first known was water. It contained two volumes of hydrogen and one volume of oxygen. It was a *binary* compound, because it was the only compound that was known. Then THENARD produced the peroxide of hydrogen. It contained one volume of each its two constituents. Yet it was a *ternary* compound, because the *binary* compound was known before; for so says DALTON, and DALTON's rules are "unexceptionable."

O but the "unexceptionable" rules have got a proviso. They are not *always* "unexceptionable." "Some cause may appear to the contrary." Yes, gentle reader, I will tell you a *standing cause to the contrary*, videlicet, the entire batch of rules are expressive of what experiment proves to be untrue. That is cause enough for me, but tastes are different, and THOMSON says the rules are "unexceptionable," and, doubtless, he is a wise and learned judge. But will he *demonstrate* that they tell truth? I wait for *that*. It is that alone will answer now. Chemistry has had enough of "unexceptionable" guides to error and mysticism. The time is come for men to examine philosophical doctrines in reference to common sense and personal experience.

METHOD OF J. J. BERZELIUS.

"There are several methods of determining the relative number of atoms in a compound. 1. The only method which gives an unquestionable result is that of determining the relative number of volumes of gas which form a compound. 2. When a substance possesses many degrees of oxidation, we determine the relative quantities of oxygen which combine with a given quantity of the combustible body. 3. When an electro-positive oxide combines with an electro negative oxide, for example, a base with an acid, the oxygen of the latter is a multiple by a whole number of the oxygen of the former."—*Traité de Chimie*, 1831, tom. iv. p. 591.

1. I agree entirely with Berzelius in considering *volumes* of elementary gases to be equivalent to *atoms*.—2. This rule leads to nothing decisive. Suppose we determine the weight of the ratios of oxygen which combine with a given quantity, say 10 parts, of the combustible body, how are we to determine whether the 10 parts represent 1 atom, 2 atoms, or 3 atoms?—3. This rule also leads to nothing. Berzelius, to be sure, twists it to a purpose. He assumes, without a shadow of proof, that the oxygen of a sulphate is so divided that the metal is in combination with a fourth part of it, and the sulphur with three-fourths. This assumption is incapable of proof; yet Berzelius offers it as a self-evident truth, and then says, "In the sulphates, the oxygen of the acid is a multiple by three of the oxygen of the base; and the saturating power of the acid is such, that it requires for its neutralisation that quantity of a protoxide of which the oxygen is equal to the third of the oxygen in the acid."

The sum of Berzelius's rules or "canons" is this:—When you have gases you can *measure* the atoms, and when you have solids you can *guess* at them.

DETERMINATION OF THE ATOMIC WEIGHTS OF THE ELEMENTS.

Among the elements enumerated at page 195, are four which have the property of assuming the state of gas at the ordinary temperature of the atmosphere. These four are oxygen, hydrogen, chlorine, and nitrogen. The remainder of the elements exist at the same temperature in the solid state.

I have stated already that the combining quantities of the elements are determinate weights, and that the combining quantities of the gases are determinate measures. Thus a cubic inch of one gas combines with a cubic inch of another gas, and not with a fractional part of a cubic inch. And it is requisite farther to state, that that determinate weight of a solid body, which combines with a cubic inch of one gas, combines also with a cubic inch, or with 2, or 3, or some entire number of cubic inches of another gas, and not with a fractional measure.

There is, consequently, a certain weight of each solid element which is equivalent in combination to a gaseous volume.

If every element could be obtained in the state of gas, the problem of determining the atomic weights could be at once solved by weighing an equal bulk of each of the gases — since in reality, the atomic weights would be neither more nor less than the specific gravities of the gases. But unfortunately this method of determining the atomic weights is limited to the few following elements :—

Oxygen	4
Chlorine	9
Hydrogen	0¼
Nitrogen	3½

to which may possibly be added—

Iodine	32
Mercury	25

Limited, however, as this method of determining the atomic weights is, it is of the greatest importance, being the only direct way of strictly comparing the elementary atoms which has yet been discovered. From the weights of equal volumes of the gaseous elements, we can form a distinct idea of the comparative weights of their atoms; but every other method of determining atomic weights affords at best what we must denominate PRESUMPTIVE *evidence*, and this, if pretty clear with respect to a number of elements, is often, in regard to others, of the most dubious description. The consequence is, that what are called the atomic weights of a good many elements are merely approximations or guesses.

Leading Principles

Upon which we are to search for the atomic weights of the elements, amidst the results of analytical experience, in the year 1834.

A volume of a gaseous element is equivalent to an atom. Its specific gravity represents its atomic weight.

That combining proportion of a fixed element which is equivalent to an atom of each of the gaseous elements, is an atom of the fixed element.

Atom of Sulphur.—In sulphurous acid, there is oxygen 4, sulphur 4; in sulphuretted hydrogen, there is hydrogen $\frac{1}{4}$, sulphur 4; in oil of vitriol, there is hydrogen $\frac{1}{4}$, sulphur 4, oxygen 8; in chloride of sulphur, there is chlorine 9, sulphur 4; in sulphate of ammonia, there is hydrogen 1, oxygen 8, nitrogen 3·5, sulphur 4.

In peroxide of hydrogen there is oxygen 4+hydrogen $\frac{1}{4}$. If we replace the hydrogen by sulphur, we get 8 of sulphurous acid. If we replace the oxygen by sulphur, we get $4\frac{1}{4}$ of sulphuretted hydrogen. In these cases, 4 of sulphur appears to be the combining proportion which is equivalent both to a volume of oxygen and a volume of hydrogen; and a strong argument in favour of this opinion is, that the specific gravity of oxygen gas is raised from 4 to 8, and that of hydrogen gas from $\frac{1}{4}$ to $4\frac{1}{4}$, by combining with 4 of sulphur, facts which lead directly to the opinion that the atomic measure of sulphur is 1 volume. Again, 9 of chlorine combines either with $\frac{1}{4}$ of hydrogen or 4 of sulphur, and 4 of sulphur either with $\frac{1}{4}$ of hydrogen or 9 of chlorine, leading one to the opinion that 9 of chlorine and 4 of sulphur are equivalent combining proportions.

These facts afford *presumptive evidence* that the atom of sulphur weighs 4, but this is the only sort of evidence we can get. There is no *absolute proof*, either *for* the supposition or *against* it. We have, therefore, a free choice betwixt 4 and another number. Choosing 4, we get, at any rate, though without proof, and solely upon presumptive evidence, a number which, if not the true one, answers all purposes of reckoning, naming, and arrangement, as well as if it had been brought out by the most rigid demonstration, and better than any other number we can conceive.

I *take it for granted*, therefore, that 4 is the atomic weight of sulphur, and that its atomic measure is one volume; but I am ready to abandon this number and adopt another, whenever evidence is produced in favour of another number more clear and convincing than that which can be offered in support of this.

Atom of Carbon.—In carbonic oxide there is oxygen 4, carbon 3; in cyanogen, there is nitrogen 3·5, carbon 3; in oxalic acid, there is hydrogen ¼, oxygen 8, carbon 3; in prussic acid, there is nitrogen 3·5, hydrogen ¼, carbon 3; in Faraday's bicarburet of hydrogen, there is hydrogen ¼, carbon 3; in Julin's chloride of carbon, there is chlorine 9, carbon 3.

Again, in carbonic acid there is oxygen 8, carbon 3; in gas of marshes there is hydrogen 1, carbon 3; in olefiant gas there is hydrogen ½, carbon 3; in sulphuret of carbon there is sulphur 16, carbon 3.

The sulphates and the oxalates, two very important classes of salts, are constituted in such a manner that, supposing the same number of atoms of metal and oxygen to be present in both, the sulphates contain 4 parts of sulphur where the oxalates contain 3 parts of carbon. It is the same with the hydrated acids. Thus oil of vitriol contains oxygen 8, hydrogen ¼, and sulphur 4; and oxalic acid contains oxygen 8, hydrogen ¼, and carbon 3.—Farther, 4 of oxygen combine with 4 of sulphur, and produce 8 of sulphurous acid; and 4 of oxygen combine with 3 of carbon, and produce 7 of carbonic oxide.—Hence 4 of sulphur and 3 of carbon are equivalent combining proportions, and the numbers expressing their atomic weights must bear that relation to one another.

Again, prussic acid contains carbon 3, hydrogen ¼, nitrogen 3½. If the hydrogen be omitted, the remainder is cyanogen. If the nitrogen be omitted, the remainder is one of the carburets of hydrogen. If the nitrogen be exchanged for an equal volume of hydrogen, the product is another carburet, namely, olefiant gas.—In all these cases, the relation which 3 of carbon bears to the atomic measure of the gaseous elements is readily discernible.

We have, in these facts, *presumptive evidence* that the atom of carbon weighs 3, and that its atomic measure is one volume.

Atom of Potassium.—In anhydrous potash there is potassium 20, oxygen 4; in caustic potash there is oxygen 4, hydrogen ¼, potassium 10; in chloride of potassium there is chlorine 9, potassium 10; in chlorate of potash there is potassium 10, chlorine 9, and oxygen 12; in the sulphurets of potassium there is potassium 10, sulphur 4, 8, 12, 16, or 20; in sulphate of potash there is sulphur 4, oxygen 8, potassium 10; in oxalate of potash there is carbon 3, oxygen 8, potassium 10; in carbonate of potash there is carbon 3, oxygen 12, potassium 20; in bicarbonate of potash there is hydrogen $\frac{1}{4}$, oxygen 12, carbon 3, and potassium 10; in cyanide of potassium there is carbon 3, nitrogen 3·5, potassium 10; in nitrate of potash there is nitrogen 3·5, oxygen 12, potassium 10.

If we compare the constitution of oil of vitriol with that of sulphate of potash; that of oxalic acid with that of oxalate of potash; that of muriatic acid with that of chloride of potassium; that of chloric acid with that of chlorate of potash; that of nitric acid with that of nitrate of potash; that of bicarbonate of potash with that of carbonate of potash; that of hydrate of potash with that of anhydrous potash; that of sulphuretted hydrogen with that of sulphuret of potassium; that of prussic acid with that of cyanide of potassium; we observe a difference that is precisely the same through the whole series, namely, $\frac{1}{4}$ *of hydrogen is invariably replaced by* 10 *of potassium.* There is no exception.

The *presumptive evidence* afforded by these facts goes to prove that the atom of potassium weighs either 10 or 20. In my opinion the number is 10; in the opinion of most other chemists it is 20, that is to say, five times as much as oxygen.

The old and the chief argument in favour of the opinion that the atomic weight of potassium is 20, is drawn from the analysis of its protoxide (potash), with regard to which it has been assumed, 1st, that 4 parts of oxygen are therein combined with the maximum quantity of potassium; 2ndly, that, being a very stable compound, it is that which contains 1 atom of each constituent. I pass over the fact, that when potash was *first* held to be present in sulphate of potash, it had not been proved that potash was a compound.

To make these assumptions bear examination, it became necessary to make a great many more assumptions. The sulphate of potash, which, according to my views, contains sulphur 4, oxygen 8, potassium 10, could not contain 24 of protoxide of potassium. Still it *was assumed* that the sulphate *did* contain it, and it accordingly became necessary to assume the constituents of that salt to be potassium 20, oxygen 16, sulphur 8; then, as this gave a quantity of oxygen 4 times as great as the quantity which, by combining with the potassium, gave rise to potash, it was assumed that in the sulphate of potash 4 parts of oxygen were combined with the metal and 12 parts with the sulphur. Thus was the *base* and the *acid* of the salt both assumed to exist without one particle of evidence to PROVE that this division of the oxygen took place.

But then the assumption that "sulphate of potash contains protoxide of potassium," was so convenient a basis for the *canons of* BERZELIUS! If the assumption is proved to be untenable, what is BERZELIUS to do with his *canons?* Truly, I fear he will in future have to fire away from some other great gun.

But what necessity is there for these assumptions? What good purpose do they answer? Is it not better to make THE SINGLE ASSUMPTION that potash contains two atoms of potassium and one atom of oxygen, than to make A THOUSAND OTHER ASSUMPTIONS, the prime tendency of which is to complicate reckoning, and to double nearly the whole of the atomic weights?

If the fixing of the atomic weight of potassium at 10 gave a number which was practically inconvenient, that might be a reason for assuming 20; but the fact is, that 10 is a number which is, beyond all comparison, more convenient than 20 as a representative of the atom of this metal. And the examination of every compound of potassium which we can bring into strict comparison with compounds of the elements whose atomic weights have been determined above, *proves distinctly* that the *weight of potassium* which invariably displaces a volume of a gaseous element, is not 20 parts, but 10. It is impossible for any presumptive evidence to come closer to demonstration than that which proves the atom of potassium to weigh 10.

I *take it for granted,* therefore, that 10 is the atomic weight of potassium; and then, by reckoning the atomic constitution of the compounds it forms with the elements just named, I *take also for granted* the following 11 propositions. The evidence which proves the accuracy of these deductions is alike potential with that which justifies the foregoing atomic weights. They stand or fall together.

1. A neutral sulphate contains 1 atom of sulphur, 2 atoms of oxygen, and 1 atom of a positive element.

HSO^2 = Oil of vitriol = Hydrosulioxin,
KSO^2 = Sulphate of potash = Kalisulioxin,
$HSO^2 + KSO^2$ = Bisulphate = Kalihydrosulinoxintetra
or KHS^2O^4 of potash.

2. A neutral carbonate contains 1 atom of carbon, 3 atoms of oxygen, and 2 atoms of a positive element.

K^2CO^3 = Carbonate of potash = Kalicaripoxintria.

3. A neutral oxalate contains 1 atom of carbon, 2 atoms of oxygen, and 1 atom of a positive element.

KCO^2 = Oxalate of potash = Kalicarioxin,
HCO^2 = Oxalic acid = Hydrocarioxin.

4. A neutral chloride contains 1 atom of chlorine and 1 atom of a positive element.

HCl = Muriatic acid = Hydrochlori,
KCl = Chloride of potassium = Kalichlori.

5. A neutral chlorate contains 1 atom of chlorine, 1 atom of a positive element, and 3 atoms of oxygen.

$HClO^3$ = Hydrate of chloric acid = Hydrochlorioxintria
$KClO^3$ = Chlorate of potash = Kalichlorioxintria.

6. A neutral nitrate contains 1 atom of nitrogen, 1 atom of a positive element, and 3 atoms of oxygen.

HZO^3 = Hydrate of nitric acid = Hydrozotioxintria,
KZO^3 = Nitrate of potash = Kalizotioxintria.

7. A neutral cyanide contains 1 atom of carbon, 1 atom of nitrogen, and 1 atom of a positive element.

HCZ = Prussic acid = Hydrocarizoti,
KCZ = Cyanide of potassium = Kalicarizoti.

8. A neutral sulphuret contains 1 atom of sulphur and 1 atom of a positive element.

9. A neutral oxide contains 1 atom of oxygen and 1 atom of a positive element.

10. A metallic protoxide contains 1 atom of oxygen and 2 atoms of a metal.

11. The hydrate of a metallic protoxide contains 1 atom of oxygen, 1 atom of hydrogen, and 1 atom of metal.

Every chemist but myself assumes the hydrates of metallic protoxides to consist of metallic protoxides combined with water. They make this assumption even in cases where the hydrates have been exposed, under common atmospheric pressure, to a *red heat*, without suffering decomposition or giving off a particle of steam. This is not very surprising to me, who know that belief is a matter of education; but I will say, that the man whose belief is wide enough to admit of such an assumption as this, must be endowed with capacity to swallow the Koran of Mahomet.

But, leaving every man to the enjoyment of his own belief, I will here simply state what *mine* is.—The hydrates of the metallic protoxides contain neither protoxides nor water, but are constituted of one atom each of metal, oxygen, and hydrogen. This is the *ultimate* constitution—what the *proximate* constitution is, I cannot tell. It may be $KH+O$, or $KO+H$, or $K+HO$; we have no means of determining *which*. I rest upon the ultimate constitution.

"Ah, but the hydrates of the protoxides often yield both protoxides and water when heated."

Of course! $KHO+KHO$ naturally produce $KKO+HHO$. There is no mystery in that. The real mystery lies in the belief that the products of the decomposition of a hydrate were the proximate constituents of the substance decomposed.

"But, in admitting the existence of only 1 atom of hydrogen in the hydrates, can we account for the various phenomena which are observable where the different hydrates come into play?"

Try: I fear not the result of your inquiries.

"But the isomeric oxides! the compounds which disengage light when heated, which lose their water, and then become insoluble in acids!"

Mighty difficulties, truly! It is the hydrate KHO which is soluble; the protoxide KKO which is insoluble. The disengagement of light marks the period when $KHO+KHO$ produces $KKO+HHO$.

"But the isomerism?"

Ripe reasoners are they who say a protoxide is similar in composition to a hydrate; deep philosophers are they who wonder that different substances do not exhibit the same properties.

ELEMENTS *whose* ATOMIC WEIGHTS *can be determined with the same certainty as that of potassium, by the analysis of substances of the classes named in the foregoing eleven propositions.*

Sodium
Lithium
Barium
Strontium
Calcium
Ammonium
Magnesium
Glucinum
Yttrium
Aluminum
Zirconium

Thorium
Manganese
Zinc
Cadmium
Iron
Nickel
Cobalt
Cerium
Lead
Tin
Bismuth

Copper
Silver
Mercury
Silicium
Titanium
Tantalum
Tellurium
Boron
Tungsten
Molybdenum
Selenium

In violation of the dictum of BERZELIUS, I have assumed the atomic weight of every element to be a multiple of the atomic weight of hydrogen. This BERZELIUS asserts to be in discordance with the results of experiment. I must confess, however, that neither his experiments nor his arguments convince my understanding, either of the precision of his numbers or the want of precision of mine. He denies that the relation of oxygen to hydrogen is as 4 to 0·25, and states it to be as 4·000000 to 249592. When this affectation of accuracy is contrasted with the reckless adoption of unfounded assumptions which I have exhibited elsewhere, I cannot avoid considering it as the whimsey of a person who can strain at a gnat and swallow a camel.

I have taken the pains to examine the results of many hundreds of first-rate chemical analyses, including a vast number of those published by BERZELIUS himself, and the consequent impression upon my mind is, that the present state of chemical art is such as cannot furnish us with results nice enough to afford an unquestionable determination of this disputed point.

ELEMENTS *whose atomic weights are determined in rela-*

tion to the atomic weight of chlorine, and with nearly as much certainty.

Bromine
Iodine
Fluorine

Elements *whose atomic weights are determined with much less certainty than the foregoing, by the analysis of their chlorides and double chlorides.*

Palladium
Platinum
Rhodium
Iridium
Gold
Osmium

Elements *whose atomic weights are guessed at from a review of their known compounds, all of which are of such a nature as do not enable us to come to very trust-worthy conclusions.*

Antimony
Vanadium
Chromium
Arsenic
Phosphorus
Uranium

The reader will observe that the comparatively greater uncertainty of the atomic weights of the last named elements depends upon the scarcity of experimental evidence. I have to regret that I have had no opportunities of perusing the continental chemical publications of the last few years, particularly those of Germany, in which the recent researches of Berzelius, Rose, Mitscherlich, &c., are detailed; otherwise, perhaps, I might have fixed the atomic weights of these elements at a different number. In cases where it was impossible for me to obtain sight of the original descriptions of important analyses, I have been obliged to draw my conclusions from the TRIMMED ABRIDGMENTS to be found in different compilations. In all such cases, I have carefully studied to avoid error, though possibly without very general success. However, it is easy for those who have access to better information than myself, to administer a suitable degree of correction. It may possibly be objected to me, in all charity, that I ought not to have published these uncertain weights without first bringing my knowledge of chemistry *up to par.* My excuse is, that chemistry is not my profession, only my amusement; and that my position as a mercantile man is such as does not warrant the expenditure of time and money which is inferred by the purchase and study of the continental chemical publications of the last ten years. Had it been possible for me to have inspected these works at a public library, I should have done so; but it was impossible. I find that there is not a public library in London or in Glasgow—possibly not one in the United Kingdom, which receives the first chemical periodical of the age, I mean POGGENDORFF's *Annalen*. It is not to be found either in the British Museum or the Royal Institution! In the public libraries of Paris and the larger towns of Germany, the scientific periodicals of all nations can be perused; but the state of the scientific literature of all the British public libraries is disgraceful to the British nation. And equally so is the miserable plan upon which nine-tenths of them are misconducted—a plan which prohibits those from using the books who could make good use of them, and devotes the sole right to use them to some old wives of professors. The truth is, that the rulers of the English people pay no great attention to any thing which they cannot immediately make a milch cow of; and the practice of the British government is nearly as much opposed to the progress of true science at this day, as were the laws of the Vatican in the days of Galileo. I appeal to the contemptible speech made lately by Sir Robert Peel to an applauding House of Commons. "*Orders of merit*," said he, "*were the proper rewards of the military*" (the desolators of the world in all ages). "*Men of science are better left to the applause of their own hearts.*" Most learned legislator! Most liberal cotton-spinner! Was *your title* the proper reward of military prowess? Pity, you hold not the dungeon-keys of an English Inquisition! Perhaps Science, like Creeds, would flourish best under a little persecution.

RULES FOR APPLYING SYMBOLS TO DENOTE THE ATOMIC COMPOSITION OF CHEMICAL COMPOUNDS.

I. Ascertain the relative proportions in weight of the ultimate elements of a compound.

II. Divide the weight of each element by the weight of its atom: the quotient is the number of atoms present.

III. Reduce all the quotients to their simplest exponents, by means of a general divisor.

IV. Arrange the symbols of the combining elements horizontally, placing that of the most positive element to the left, and that of the most negative to the right.

V. Place the exponent of each symbol, as determined by Rule III., immediately after the symbol, and at the upper part of the line, unless the exponent happens to be 1, when it is to be omitted.

FIRST EXAMPLE.—*Sulphate of Barytes.*

RULE I.—The analysis of sulphate of barytes proves the relative proportions in weight of its elements to be—

Barium,.........593220.
Sulphur,.........135594.
Oxygen,.........271186.

RULE II.—The weight of the atom of barium is 17·5; of sulphur, 4; and of oxygen, 4.

The quotient of 593220 divided by 17·5 is 338983.
The quotient of 135594 divided by 4 is 338985.
The quotient of 271186 divided by 4 is 677965.

RULE III.—Dividing the whole of these quotients by the smallest, as a general divisor, the exponents of the number of atoms prove to be

Barium, 1; Sulphur, 1; Oxygen, 2.

RULE IV.—The symbols of these three elements are

BaSO.

RULE V.—The symbol for sulphate of barytes is therefore

$BaSO^2$.

SECOND EXAMPLE.—*Iron Pyrites.*

RULE I.—100 parts of iron pyrites yield 46 parts of iron, and 54 parts of sulphur.

RULE II.—The weight of the atom of iron is 7, of sulphur 4.

The quotient of 46 divided by 7 is 6·6.˙
The quotient of 54 divided by 4 is 13·5.

RULE. III.—These quotients are obviously in the relation of Iron, 1 + Sulphur, 2.

RULE IV.—The symbols of these two elements are FeS.

RULE V.—The symbol for *iron pyrites* is therefore FeS^2.

THIRD EXAMPLE.—*Chloride of Silver.*

100 parts of silver produce 132·75 parts of chloride of silver, containing 32·75 parts of chlorine.

The atomic weight of silver is 27·5, of chlorine, 9.
The quotient of 100 divided by 27·5 is 3·636.
The quotient of 32·75 divided by 9 is 3·638.
These quotients are in the relation of 1 to 1.
The symbols of the two elements are ArCl;
Therefore the symbol for chloride of silver is ArCl.

FORMULA EMPLOYED IN CALCULATIONS RESPECTING ATOMIC COMPOSITION.

m = the mass or quantity of a substance.
$a.\ w.$ = the weight of its atom.
$n.\ a.$ = the number of atoms which constitute the mass.

$$1.\text{—}\ m = a.w \times n.a.$$

$$2.\text{—}\ \frac{m}{a.w} = n.a.$$

$$3.\text{—}\ \frac{m}{n.a} = a.w.$$

1. The MASS is equal to the *atomic weight* multiplied by the *number of atoms*.

2. The *Mass*, divided by the *atomic weight*, is equal to the NUMBER OF ATOMS.

3. The *Mass*, divided by the *number of atoms*, is equal to the ATOMIC WEIGHT.

RULES FOR FORMING NAMES TO DENOTE THE ATOMIC CONSTITUTION OF CHEMICAL COMPOUNDS.

a. Compounds containing two Elements.

I.—Composition = 1 *atom of each element*:—Put the NAMES OF THE ATOMS together, so as to form one word, beginning with that of the positive element.

EXAMPLE:—BaCl = Barichlori.

II.—Composition = 2 *positive atoms and* 1 *negative atom*.—Form the name according to Rule I., and add *p*.

EXAMPLE:—Ba^2Cl = Barichlorip.

III.—Composition = 1 *positive atom and* 2 *negative atoms*.—Form the name according to Rule I., and add *n*.

EXAMPLE:—$BaCl^2$ = Barichlorin.

IV.—Composition = 1 *positive atom and more than 2 negative atoms, or* 1 *negative atom and more than 2 positive atoms.*—Form the name according to the preceding rules, and add to it from the Table of Numerical Exponents, page 195, a word indicative of the number of atoms present of the element in excess.

EXAMPLES :—Ba^3Cl = Barichloriptria.
$BaCl^4$ = Barichlorintetra.

V.—Composition = *More than* 1 *positive atom with more than* 1 *negative atom.*—Form the name according to Rules I., II., III., and add from the table of the numerical exponents, page 195, words indicative of the number of atoms present of each element, placing the numerical exponent of the positive element first.

EXAMPLE :—Ba^4Cl^3 = Barichloriptetratria.

---

b. Compounds containing more than two Elements.

VI.—Composition = 1 *atom of each element.*—Form the name according to Rule I.

EXAMPLES :—$BaHO$ = Barihydroxi.
$KCZS$ = Kalicarizotisuli.

VII.—Composition, = *three elements, viz.* 1 *atom each of two positive elements, and* 2 *or more atoms of a negative element.*—Form the name according to Rules III. and IV.

EXAMPLES :—$BaSO^2$ = Barisulioxin.
KZO^3 = Kalizotioxintria.

VIII.—Composition = *Three elements,* viz. 2 *or more positive atoms,* 1 *intermediate atom, and* 3 *or more negative atoms.* Form a name for the positive and intermediate atoms, according to Rules II. or IV., and add thereto the atomic name and numerical exponent of the 3 negative atoms, according to Rule IV.

EXAMPLES :—Ca^2CO^3 = Calcicaripoxintria.
K^3AsS^5 = Kaliarsiptriasulinpenta.

IX.—Composition = *Three elements*, viz., 1 *positive atom,* 2 *intermediate atoms, and* 3 *negative atoms.* Form a name for the 1 positive and the 2 intermediate atoms, according to Rule III., and add thereto the atomic name and numerical exponent of the 3 negative atoms, according to Rule IV.

EXAMPLES :—$AmPt^2Cl^3$ = Ammiplatinchlorintria.
KTi^2F^3 = Kalititinflurintria.

X.—Composition = *Four elements, the most negative in greatest excess, thus,* 1, 1, 2, 4. Form a name for the three first elements according to Rule VII., and add the name for the last element according to Rule IV.

Examples:—KHS^2O^1 = Kalihydrosulinoxintetra.
$KThS^2O^4$ = Kalithorisulinoxintetra.

XI.—Composition = *Four elements in the relation of* 2, 1, 3, 3. Form a name for the three first elements according to Rule VIII., and add the name for the last element according to Rule IV.

Example:—$K^2FeC^3Z^3$ = Kaliferipcarintriazotintria.

XII.—Composition = *Any number of Elements in any number of Atoms.* The name makes two words. Form the first word by adding together the names of the atoms of each element, according to Rules I. and VI. Form the second word by adding together the numerical exponents of the atomic names in the first word, arranging them in the same order as the atomic names to which they refer.

Examples:—

$K^2U^3S^5O^{10}$ = Kaliurisulioxi Diatriapentadeca
$BeAl^2Si^9O^6$ = Berialisilioxi Monadiaennahexa
$Pb^5U^3O^4$ = Pluminrioxi Pentatriatetra
$Sb^6S^4O^1$ = Stibisulioxi Hexatetramona
$K^2Sb^6O^5$ = Kalistibioxi Diahexapenta.

Atomic Name and Symbol of Water of Crystallisation.

I. Place the atomic name or symbol of water of crystallisation always *after* the atomic name or symbol of the compound it belongs to, i. e. always consider water as negative towards any other compound.

II. Place the numerical exponent of the atoms of water, after the symbol of the water, and the numerical exponent of the atoms of the salt *before* the symbol of the water, putting both at the upper part of the line, and inserting the sign + between the symbol of the dry salt and the symbol of the water. When the relations are 1 atom of the compound, and 1, 2, 3, &c., atoms of water, or 1 atom of water, and more than 1 atom of the compound, it is only necessary to put the number which denotes the atoms of the substance which is present in greatest quantity. And, when there is only one atom of the dry salt, the sign + may be omitted.

EXAMPLES :—

Atoms of salt, say Sulphate of Soda.	Atoms of Water.	Symbol.	Name.
2	1	$NSO^2+{}^2Aq$	Natisulioxin Aquip
3	2	$NSO^2+{}^3Aq^2$	Natisulioxin Aquiptriadia
1	1	NSO^2Aq	Natisulioxin Aqui
1	2	NSO^2Aq^2	Natisulioxin Aquin
2	3	$NSO^2+{}^2Aq^3$	Natisulioxin Aquindiatria
1	12	NSO^2Aq^{12}	Natisulioxin Aquindodeca

Crystallised salts containing ALCOHOL instead of *water of crystallisation* may be designated in a similar manner, using the term *Alcoi* to signify an *atom of alcohol.*

APPLICATION OF THESE SYMBOLS AND NAMES TO VARIOUS COMPOUNDS DESCRIBED IN CHEMICAL RECREATIONS.

COMPOUNDS OF POTASSIUM, see table at page 174.

The numerical exponents of the atoms are discovered by dividing the weights put in the table referred to, by the atomic weights of the elements, presented in the table at page 195. See Rules II. and III., for applying symbols. The rules referred to below are those for forming names.

Present Names.	Symbols.	New Names.	Rules.
Protoxide of Potassium	K^2O	Kalioxip	II.
Peroxide of potassium	K^2O^3	Kalioxindiatria	V.
Caustic potash.	KHO	Kalihydroxi	VI.
1st Sulphuret of potassium	KS	Kalisuli	I.
2d Do.	KS^2	Kalisulin	III.
3d Do.	KS^3	Kalisulintria	IV.
4th Do.	KS^4	Kalisulintetra	IV.
5th Do.	KS^5	Kalisulinpenta	IV.
Sulphate of potash	KSO^2	Kalisulioxin	VII.
Bisulphate of potash	KHS^2O^4	Kalihydrosulinoxintetra	X.
Chloride of potassium	KCl	Kalichlori	I.
Chlorate of potash	$KClO^3$	Kalichlorioxintria	VII.
Oxalate of potash	KCO^2	Kalicarioxin	VII.
Carbonate of potash.	K^2CO^3	Kalicaripoxintria	VIII.
Nitrate of potash	KZO^3	Kalizotioxintria	VII.

COMPOUNDS OF LEAD, page 141.

Present Names.	Symbols.	New Names.	Rules
Yellow oxide of lead	Pb^2O	Plumioxip	II.
Orange oxide of lead	Pb^3O^3	Plumioxiptriadia	V.
Red oxide of lead	Pb^4O^3	Plumioxiptetratria	V.
Brown oxide of lead	PbO	Plumioxi	I.
Chloride of lead.	$PbCl$	Plumichlori	I.
Sulphuret of lead	PbS	Plumisuli	I.
Sulphate of lead	$PbSO^2$	Plumisulioxin	VII.
Nitrate of lead	$PbZO^3$	Plumizotioxintria	VII.

COMPOUNDS OF HYDROGEN, page 93.

Present Names.	Symbols.	New Names.	Rules.
Peroxide of hydrogen	HO	Hydroxi	I.
Water	H^2O	Hydroxip	II.
Sulphuretted hydrog. gas	HS	Hydrosuli	I.
Muriatic acid gas	HCl	Hydrochlori	I.
Hydrate of chloric acid	$HClO^3$	Hydrochlorioxintria	VII.
Hydrofluoric acid	HF	Hydrofluri	I.
Hydrate of nitric acid	HZO^3	Hydrozotioxintria	VII.
Oil of vitriol	HSO^2	Hydrosulioxin	VII.
Effloresced oxalic acid	HCO^2	Hydrocarioxin	VII.
Bicarburet of hydrogen	HC	Hydrocari	I.
Olefiant gas	H^2C	Hydrocarip	II.
Gas of marshes	H^4C	Hydrocariptetra	IV.
Prussic acid	HCZ	Hydrocarizoti	VI.
Ammonia	H^3Z	Hydrozotiptria	IV.
Hydrate of Lime	$CaHO$	Calcihydroxi	VI.
Quick lime	Ca^2O	Calcioxip	II.
Hydrate of silica	$HSiO$	Hydrosilioxi	VI.
Silica	Si^2O	Silioxip	II.

Compounds of Ammonium, page 157.

Present Names.	Symbols.	New Names.	Rules.
Hydrosulphuret of ammo.	AmS	Ammisuli	I.
Sulphate of ammonia	$AmSO^2$	Ammisulioxin	VII.
Nitrate of ammonia	AmZO	Ammizotioxintria	VII.
Muriate of ammonia	AmCl	Ammichlori	I.
Oxalate of ammonia	$Am\,CO^2$	Ammicarioxin	VII.
Carbonate of ammonia	Am^2CO^3	Ammicaripoxintria	VIII.

These examples are sufficient to show in what manner we can form a *symbol* and a *name* for any compound of which we know the relative proportions by weight of the ultimate constituents. They also show the system to be such that it can furnish symbols and names not merely for all the compounds now known, but for all that can be discovered hereafter. No compound of known elements can be *imagined* for which the system does not afford an unemployed, precise and significant name, producible and comprehensible by the merest tyro in the science.

EFFECT OF NEW DISCOVERIES UPON THIS NOMENCLATURE.

Imagine the discovery of

(*a*) A new compound of known elements,

(*b*) A new element,

(*c*) Compounds of the new element with known elements,

(*d*) A new element as an ingredient of one of the known elements,

(*e*) A different atomic weight for a known element.

These appear to me to be probable discoveries. It is needless to provide for what are improbable.

(*a*) *New compounds of known elements.* See the conclusion of the last section. The system provides a name, symbol, and place for all the compounds that can possibly occur.

(*b*) *A new element.* Whenever a new element is found, we must discover its electrical relations and decomposing powers, and thus determine its situation among the other elements in the table at page 195. We must give it a name as different as possible in sound and letters from the names of the other elements. We must then abridge the name to *two syllables* to produce the *name of its atom*, abridge it to *one letter* to produce the *symbol of its atom*, and lastly, determine by experiment and analogy the weight of its atom.

(*c*) *Compounds of the new element with known elements.* These will, of course, be in the same predicament as (*a*) *New compounds of known elements.* When once we have fixed the *atomic weight*, *atomic symbol*, and *atomic name* of a new element, we have provided names for every one of its compounds, which either nature or art can produce, every one of which names must, like the compounds they will belong to, be essentially different from each other.

(*d*) *A new element as an ingredient of one of the known elements.* EXAMPLE:—Suppose it should be discovered that chlorine contains two atoms of oxygen and one atom of an hitherto-unknown element. The atomic weight of the new element would in that case be 1. We could either retain for it the name chlorine, or give it a new name. If we retained the present name, the following changes would be necessary on a few of its compounds.

Present Names.	Proposed Names. Chlorine = 9.	Future Names. Chlorine = { Oxygen 8. Chlorine 1.
Muriatic acid	Hydrochlori	Hydroclorioxin
Chloride of silver	Argichlori	Argichlorioxin
Chloride of potassium	Kalichlori	Kalichlorioxin
Chlorate of potash	Kalichlorioxintria	Kalichlorioxinpenta
Protoxide of chlorine	Chlorioxip	Chlorioxipdiapenta
Deutoxide of chlor.	Chlorioxin	Chlorioxintetra
Chloride of sulphur	Chlorisulip	Chlorisulipoxintetra
Perchloride of sulp.	Chlorisuli	Chlorisulioxin

The atomic weights of the compounds of chlorine *would remain the same as at present*, and the change in the name would be limited to an *affix* denoting the number of atoms of oxygen present.

(*e*) *A different Atomic Weight for a known Element.*—As the atomic weights of about a third of the elements are determined with considerable uncertainty, this is a discovery daily to be expected. It is also one that, when it comes, must *change the terminations* of the names of all the compounds of that element. Much as this is to be regretted, it cannot be provided against. No theory can provide for things unknown, and no nomenclature, which pretends to express *atomic constitution*, can do so really, without being liable to the changes incidental upon new discoveries.

Let us see the nature of the changes that would be necessary if the atomic weight of mercury came to be considered 50 instead of 25.

Atom of Mercury = 25.		Atom of Mercury = 50.	
$Mr\,O$	Merioxiptetra	$Mr^2\,O$	Merioxip
$Mr^2\,O$	Merioxip	$Mr\,O$	Merioxi
$Mr^2\,S$	Merisulip	$Mr\,S$	Merisuli
$Mr\,S$	Merisuli	$Mr\,S^2$	Merisulin
$Mr^2\,Cl$	Mericlorip	$Mr\,Cl$	Merichlori
$Mr\,Cl$	Merichlori	$Mr\,Cl^2$	Merichlorin

This removal of a name from one compound to another is liable to give rise to mistakes; and this liability we shall be unable to get rid of, until the atomic weights of the solid elements come to be determined by methods as precise as those by which we determine the atomic weights of the gaseous elements.

It would be easy to exhibit a variety of other examples of treatment of imaginary discoveries, but the foregoing are sufficient to show that the spirit of this system is as accommodating as the principle upon which it proceeds of *expressing atomic constitution* can possibly admit. A nomenclature of this sort can only be rendered *perfect* when the atomic theory is perfect. In the mean time, a nomenclature which expresses atomic constitution in exact agreement with the extent of our knowledge, imperfect though it be, is the most useful nomenclature we can have.

PROXIMATE AND ULTIMATE CONSTITUTION.

I HAVE denounced the doctrine of *proximate constitution* as the ever-flowing source of chemical blunders, whilst in treating of the limits of combination, and in the discrimination of positive and negative substances, I have admitted the doctrine in its substantial features. Permit me to reconcile these apparent contradictions.

According to my theoretical notions, every compound is formed of a *positive* substance and a *negative* substance, each of which *may be* either an element or a compound. Thus the compound AB contains the positive element A and the negative element B. The compound AAB contains the positive element A and the comparatively negative compound AB. The compound ABB contains the comparatively positive compound AB and the negative element B. Yet this is all matter of theory and opinion, for I am unable to prove that the compound AAB is not formed by the direct combination of AA with B, and the compound ABB by the direct combination of A with BB. The latter is the prevailing theory—the theory of DALTON; and though I disbelieve it, and consider it utterly inconsistent with the facts of chemistry, it may be true. But even admitting its truth, the light it throws on chemical composition is a feeble one; for what does it discover when brought to bear upon the compound ABC? Does this compound arise from the simultaneous combination of the three elements, or does AB combine with C, or AC with B, or A with BC? And in the case of the compound ABCC—is this constituted of A + BCC, or AB + CC, or ABC + C, or AC + BC, or AAC + BBCCC?—These are cases of perplexity, in the disentanglement of which the atomic theory is of no service. It boots not that we know how many elementary atoms of A, B, and C are contained in a given compound. These are but the *ultimate* constituents; and what we want to know is, how these are combined together into *proximate* constituents.

This is a problem for future times to solve, and it is a problem of that importance that we are not warranted in *assuming* its solution, merely for the purpose of grounding a nomenclature and a system of arrangement upon the assumed solution. Yet this is done in the antiphlogistic nomenclature and theory. *It is assumed that sulphate of barytes contains barytes and sulphuric acid, that nitrate of potash contains potash and nitric acid, that caustic soda contains protoxide of sodium and water;*—and these assumptions form the groundwork of the French theory and nomenclature—the groundwork of the theory adopted by the gifted Berzelius, who has spent twenty years in vain attempts to establish it. The root of the system of this chemist is, that in the sulphate of lead the oxygen is so divided between the sulphur and the lead, that the portion combined with the former bears to the portion combined with the latter the ratio of 3 to 1. I hesitate not to say that *this is an assumption incapable of proof.*

Let us examine the formation of sulphate of lead with a view to discover its proximate constituents :—

a. When 4 parts of sulphur are converted into sulphuric acid by digestion with nitric acid, and the solution is precipitated by a solution of lead, the resulting sulphate of lead weighs 38, containing 26 of lead, and consequently 8 of oxygen.

b. When 26 parts of lead are dissolved in nitric acid, and the solution is precipitated by sulphuric acid or by the solution of a sulphate, the resulting sulphate of lead weighs 38, containing 4 of sulphur and 8 of oxygen.

c. When 30 parts of sulphuret of lead, containing lead 26 and sulphur 4, are converted by oxidation into sulphate of lead, the weight of the product is 38, including 8 of oxygen.

d. When 35 parts of chloride of lead, which contain chlorine 9 and lead 26, are precipitated by sulphuric acid, the resulting sulphate of lead weighs 38, and contains 4 of sulphur and 8 of oxygen.

e. When 30 parts of brown oxide of lead, which contains lead 26, oxygen 4, are exposed to an atmosphere of sulphurous acid gas, they absorb 8 parts of that acid, equal to oxygen 4 and sulphur 4, and produce 38 parts of sulphate of lead.

The information afforded by the above experiments is, that sulphate of lead is composed of—

Lead	26
Sulphur	4
Oxygen	8
	38

But none of these experiments afford the least insight into the manner in which these elements are combined together. The assumption that one-fourth of the oxygen is combined with the lead and three-fourths with the sulphur, is perfectly gratuitous.

The most direct of the whole five experiments, *e*, is in favour of the conclusion that sulphate of lead is $PbO+SO$, a conclusion very different from that which Berzelius comes to, but which agrees precisely with my opinion that 26 parts of lead is the quantity which is equivalent in combination to a volume of hydrogen.

It is very well to admit the doctrine of proximate constitution in theory, because it is useful in explaining a variety of phenomena, such as chemical combinations, electrical decompositions, and the like. But when we come to arrange the products of chemistry into a system, and to give them systematic names, the only safe way to view them is in relation to their ultimate constitution. It is only by founding a nomenclature upon this basis, that we can hope to avoid the perplexities which arise from the *guess-work* of the proximatists.

But, it may be said, in rejecting proximate constitution, and stating only the ultimate constitution of compounds. you give false notions of secondary compounds, the properties of which depend upon the nature of their proximate constituents. Thus sulphate of barytes derives its properties from the sulphuric acid and barytes which compose it.

I reply, No!—Sulphate of barytes derives its properties from the barium, sulphur, and oxygen which compose it, just as sulphuric acid and barytes, considered as distinct compounds, derive *their* properties from the same ultimate elements. In short, viewed in any light, it is the ultimate elements which determine the character of the compounds. There is a fashion, but no utility, in assuming proximate constitution, as the basis of a systematic nomenclature.

The admirers of the latter doctrine will, I hope, be gratified to find, that notwithstanding all my prejudices to the contrary, I have admitted the existence of at least *two proximate constituents* of compounds; namely, Ammonium and Water of Crystallisation. I shall leave to them, as a "Chemical Recreation," the solution of the problem *why I have done this.*

A CHEMICAL SYSTEM.

The principle of the following system is the invention of Leopold Gmelin, and is the one employed in his masterly work, the *Handbuch der Theoretischen Chemie*, Frankfort, 1827. I have partially put it in practice in *Chemical Recreations*, pages 67—184.

Each element is allowed a distinct section, the first section being devoted to oxygen, and the last to potassium.

The first section treats of oxygen alone. The second treats first of sulphur, and then of the compounds of sulphur with oxygen. The third treats first of nitrogen, then of the compounds of nitrogen and oxygen, next of the compounds of nitrogen with sulphur, and of nitrogen with sulphur and oxygen. The fourth section treats of chlorine, of the compounds of chlorine and oxygen, of chlorine and sulphur, of chlorine with sulphur and oxygen, of chlorine and nitrogen, of chlorine with nitrogen and oxygen, of chlorine with nitrogen and sulphur, of chlorine with nitrogen, sulphur, and oxygen.

The compounds which we may conceive to be formed by these four elements, supposing no compound to contain above one atom of each element, would require the following symbols for their expression.

O
S
SO
Z
ZO
ZS
ZSO

Cl
ClO
ClS
ClSO
ClZ
ClZO
ClZS
ClZSO

It is easy to see, from the above small specimen, that this is a system which not only embraces every known compound, but provides a place for it, out of which it cannot be removed without an impropriety so very evident as to be at once pointed out by the systematic name of the compound.

The advantages of this system are gained by placing every compound under the head of the element which forms its *most positive* constituent, while the positive elements are, at the same time, placed *last* in the system. And the very advantageous agreement of the nomenclature and the system, is obtained by placing the name of the positive element of a compound at the *beginning* of the compound name.

A system such as this, is exceedingly well adapted to be the basis of a book of reference. At present, if you want to read the chemical history of chloride of barium, you do not know, upon taking up a chemical book, whether it will be found in the chapter on chlorides or in that on barium. But the new name of this compound, *Barichlori*, informs you that it will be found in the fifth chapter of the section headed Barium, the first chapter of that section being devoted to barium, the second to compounds of barium and oxygen, the third to compounds of barium and sulphur, and the fourth to compounds of barium and nitrogen. So that these five first chapters of the section on barium must, in the spirit of this system, treat of the following known compounds in the following order.

Barioxip = Barytes
Barioxi = Peroxide of Barium
Barisuli = Sulphuret of Barium
Barisulioxin = Sulphate of Barytes
Barizotioxintria = Nitrate of Barytes
Barichlori = Chloride of Barium
Barichlorioxintria = Chlorate of Barytes

The following tables are constructed upon this system, and I hope that the explanation now given will render them intelligible. My object in drawing them up, was to show the actual applicability of my Nomenclature and Theory to the compounds with which chemists are best acquainted. I could have easily extended the tables, but not without increasing the size of the book, which was a point to be avoided.

Explanation of the Tables.—The first column embraces the new names, exhibiting the atomic constitution of the compounds. The second column contains the new symbolic representations of the compounds. The third column shows the weight of the atom of each substance, and the fourth column gives the most common English names, both of the elements and compounds.

The names and symbols of the salts are given under the name of their most negative constituent, leaving the oxygen out of consideration. Thus the *sulphates* are exemplified by Kalisulioxin, KSO^2, under the head of "sulphur." All other sulphates are denoted by SO^2, added to the *symbol of the atom*, or by sulioxin added to the *name of the atom*, of their electro-positive elements. *Bari*sulioxin, $BaSO^2$, is sulphate of barytes. *Hydro*sulioxin, HSO^2, is hydrate of sulphuric acid. *Plumi*sulioxin, $PlSO^2$, is sulphate of lead.

Atomic Names.	Symbols.	Weights.	Common Names.
Oxi.	O.	4	Oxygen.
Suli.	S.	4	Sulphur.
Sulioxi	SO	8	Sulphurous Acid
Sulioxindiatria	S^2O^3	20	Dry Sulphuric Acid
———			Salts:—
Kalisuli	KS	14	Sulphuret of Potassium
Kalisulioxin	KSO^2	22	Sulphate of Potash
Kalisulinoxintria	KS^2O^3	30	Hyposulphate of Pot.
Kalisulioxi Diadiatria	$K^2S^2O^3$	40	Sulphite of Potash ?
Kalihydrosulioxin	$KHSO^2$	22·25	Sulphite of Potash ?
Kalisulioxi	KSO	18	Hyposulphite of Potash
Kalihydrosulinoxin	KHS^2O^2	26·25	Double do. with Hydrogen
Kaliargisulinoxin	$KArS^2O^2$	53·5	Double do. with Silver
Zoti.	Z.	3·5	Azote. Nitrogen.
Zotioxip	Z^2O	11	Nitrous Oxide
Zotioxi	ZO	7·5	Nitrous Gas
Zotioxin	ZO^2	11·5	Nitrous Acid
———			Salts:—
Kalizotioxintria	KZO^3	25·5	Nitrate of Potash
Kalizotioxin	KZO^2	21·5	Hyponitrite of Potash
Kalizotioxi	KZO	17 5	Nitrous Oxide and Potash (Nitroxis)
Natizotioxi	NZO	13·5	Nitrous Oxide and Soda

Chlori.	Cl.	9	Chlorine.
Chlorioxip	Cl^2O	22	Protoxide of Chlorine
Chlorioxin	ClO^2	17	Peroxide of Chlorine
Chlorisulin	ClS^2	17	Dichloride of Sulphur
Chlorisuli	ClS	13	Chloride of Sulphur
Chlorizotiptria	Cl^3Z	30·5	Chloride of Azote
———			SALTS:—
Kalichlori	KCl	19	Chloride of Potassium
Kalichlorioxintria	$KClO^3$	31	Chlorate of Potash
Kalichlorioxintetra	$KClO^4$	35	Perchlorate of Potash
Bromi.	**Bm.**	**20**	**Bromine.**
Bromisuli	BmS	24	Bromide of Sulphur
Bromichlori	$BmCl$	?	Chloride of Bromine
———			SALTS:—
Kalibromi	KBm	30	Bromide of Potassium
Kalibromioxintria	$KBmO^3$	42	Bromate of Potash
Iodi.	**I.**	**32**	**Iodine.**
Iodisulin	IS^2	40	Diodide of Sulphur
Iodizotiptria	I^3Z	99·5	Iodide of Azote
Iodichlorin	ICl^2	50	Iodide of Chlorine
Iodibromi	IBm	?	Iodide of Bromine
———			SALTS:—
Kaliodi	KI	42	Iodide of Potassium
Kaliodioxintria	KIO^3	54	Iodate of Potash
Fluri.	**F.**	**4·5**	**Fluorine.**
			SALTS:—
Kalifluri	KF	14·5	Fluoride of Potassium
Kaliwolintriaflurin	KW^3F^2	43	Fluotungstates
Kaliborintriaflurintetra	KB^3F^4	31	Fluoborates
Kalitaninflurintria	KTa^2F^3	53·5	Fluotantalates
Kalititinflurintria	KTi^2F^3	29·5	Fluotitaniates
Kalisilinflurintria	KSi^2F^3	27·5	Fluosilicates

Phosi.	P.	4	Phosphorus.
Phosioxiptetra	P^4O	20	Hypophosphorous Acid
Phosioxiptetratria	P^4O^3	28	Phosphorous Acid
Phosioxipdiatria	P^2O^3	20	Phosphoric Acid
Phosichlorindiatria	P^2Cl^3	35	Fluid Chloride of Phos.
Phosichlorintria	PCl^3	31	Solid Chloride of Phos.
Phosibromintria	PBm^3	64	Bromide of Phosphorus
Phosiodindiatria	P^2I^3	104	Sesquiiodide of Phos.
Phosiodintria	PI^3	100	Periodide of Phos.
Seli.	Se.	10	Selenium.
Selioxi	SeO	14	Selenious Acid
Selisulin	SeS^2	18	Sulphuret of Selenium
Selichlorip	Se^2Cl	29	Liquid Chloride of Selenium
Selichlorin	$SeCl^2$	28	Solid Chloride of Selen.
———			SALTS :—
Kaliseli	KSe	20	Seleniuret of Potassium
Kaliselioxin	$KSeO^2$	28	Seleniate of Potash
Kalihydroselioxin	$KHSeO^2$	28·25	Selenite of Potash
Arsi.	As.	9·5	Arsenic.
Arsioxiptetratria	As^4O^3	50	Arsenious Acid
Arsioxintetrapenta	As^4O^5	58	Arsenic Acid
Arsisuli	AsS	13·5	Sulphuret a. Realgar
Arsisulindiatria	As^2S^3	31	b. Orpiment
Arsisulindiapenta	As^2S^5	39	c. Persulph.
Arsichlorindiatria	As^2Cl^3	46	Chloride of Arsenic
Arsiflurindiatria	As^2F^3	32·5	Fluoride of Arsenic
———			*Examples of Arseniates:*
Kaliarsioxi Triadiatetra	$K^3As^2O^4$	65	—of Potash a. Basic
Kaliarsioxi Tetratetrahepta	$K^4As^4O^7$	106	b. Neutral
Kaliarsinoxintria	KAs^2O^3	41	c. Acid
Calciarsioxi Tetratetrahepta	$Ca^4As^4O^7$	86	—of Lime
Calciarsioxi Tetratetrahepta Aquinhexa	$Ca^4As^1O^7Aq^6$	113	Ditto Pharmacolite

Arsi.	As.	9·5	Arsenic.
Natiammiarsinoxinpenta	$NaAm\,As^2O^5$	49·5	—of Soda and Ammon.
Kalinatiarsioxi Diadiatetrahepta	$K^2N^2As^4O^7$	98	—of Potash and Soda
Kaliarsinoxin	KAs^2O^2	37	Arsenite of Potash
———			*Double Sulphurets* :—
Kaliarsisuli Triadiapenta	$K^3As^2S^5$	69	a
Kaliarsisuli Triadiahexa	$K^3As^2S^6$	73	b
Kaliarsisuli Triadiaocta	$K^3As^2S^8$	81	c
Kaliarsisulin	$KAsS^2$	27·5	d
Kaliarsisuli Diadiapenta	$K^2As^2S^5$	59	e
Kaliarsisuli Diadiahepta	$K^2As^2S^7$	67	f
Kaliarsinsulintria	KAs^2S^3	41	g
Kaliarsinsulintetra	KAs^2S^4	45	h
Kaliarsinsulinhexa	KAs^2S^6	53	i
Chromi.	**Cr.**	**7**	**Chromium.**
Chromioxiptetratria	Cr^4O^3	40	Green Oxide of Chro.
Chromioxi	CrO	11	Brown Oxide of Chro.
Chromioxindiatria	Cr^2O^3	26	Chromic Acid, dry
Chromisulindiatria	Cr^2S^3	26	Sulphuret of Chro.
Chromisulioxintria	$CrSO^3$	23	Sulphuric Acid, Chromic Acid
Chromichlorin	$CrCl^2$	25	Chloride of Chromium
Chromichlorindiatria	Cr^2Cl^3	41	Perchloride of Chro.
Chromifluri	CrF	11·5	Fluoride of Chromium
Chromiflurintria	CrF^3	20·5	Perfluoride of Chro.
———			SALTS :—
Kalichromioxin	$KCrO^2$	25	Chromate of Potash
Ammichromioxin	$AmCrO^2$	19·5	—— of Ammonia
Barichromioxin	$BaCrO^2$	32·5	—— of Barytes
Kalichromintriasulintetraoxinocta Aquindodeca	$KCr^3S^4O^8 + Aq^{12}$	133	Chrome Alum crystallised.

Chromi.	Cr.	7	Chromium.
			Presumed varieties of the CHROMATES, *say of Potash* :—
Kalichromipoxintria	K^2CrO^3	39	Subchromate, = $KO + KO + CrO$
Kalichromioxin	$KCrO^2$	25	Chromate, = $KO + CrO$
Kalichrominoxintria	KCr^2O^3	36	Bichromate, = $KO + CrO + CrO$
Vani.	**V.**	**17**	**Vanadium.**
Vanioxip	V^2O	38	Suboxide of vanadium
Vanioxi	VO	21	Vanadic oxide
Vanioxindiatria	V^2O^3	46	Vanadic acid, dry
Vanioxintetrapenta	V^4O^5	88	Purple intermediate oxide, Subvanadate of vanadium
Vanioxintriatetra	V^3O^4	67	Vanadate of vanadium
Qu. if hydrates?		?	Bivanadate of vanadi.
		?	Supervanadate of vana.
Vanisulin	VS^2	25	Sulphuret a
Vanisulintria	VS^3	29	—— b
Qu. if hydrates?	VS^2O^4	?	Sulphate of vanadium?
	VS^3O^6	?	Hypersulphate of vanadium?
Vanichlori	VCl	26	Chloride of vanadium
Vanichlorindiatria	V^2Cl^3	61	Ditto
Vanibromi	VBm	37	Bromide of vanadium
Vaniodi	VI	49	Iodide of vanadium
Vaniodindiatria	V^2I^3	130	Ditto
Vanifluri	VF	21·5	Fluoride of vanadium
Vaniflurindiatria	V^2F^3	47·5	Ditto
Vanichromioxin	$VCrO^2$	32	Chromate of vanadium
———			SALTS :—
Ammivanioxin	$AmVO^2$	29·5	Vanadate of ammon.
Ammivanioxi	$AmVO$	25·5	Vanadite of ammon.
Kalivanioxi	KVO	31	Vanadite of potash
Kalivanioxin	KVO^2	35	Vanadate of potash
Kalihydrovaninoxintetra	KHV^2O^4	60·25	Bivanadate of potash

Moli.	Mu.	12	Molybdenum.
Molioxip	Mo^2O	28	Prutoxide of Molybd.
Molioxi	MoO	16	Deutoxide do.
Molioxintriatetra	Mo^3O^4	52	Blue oxide, Thomson's quatermolybdated deutoxide of molybd.
Molioxindiatria	Mo^2O^3	36	Molybdic acid
Molisulin	MoS^2	20	Bisulphide of Molybd.
Molisulintria	MoS^3	24	Tersulphide
Molisulintetra	MoS^4	28	Quatersulphide
Molichlori	$MoCl$	21	Chloride
Molichlorin	$MoCl^2$	30	Bichloride
Molichlorintria	$MoCl^3$	39	Terchloride
——			SALTS:—
Barimolioxin	$BaMoO^2$	37·5	Molybdate of barytes
Magimolioxin	$MgMoO^2$	23	—— of magnesia
Ammimolioxin	$AmMoO^2$	24·5	—— of ammonia
Kalimolisulintetra	$KMoS^4$	38	Sulpho-molybdate of potassium
Kalimulisulinpenta	$KMoS^5$	42	Hypersulphomolybdate of potassium

⁂ The sulpho-molybdates are very variable in composition. Molybdenum forms double salts with electropositive metals and Cl—I—Bm—F—and CZ.

Woli.	W.	8	Tungsten. Wolfram.
Wolioxiptria	W^3O	28	Oxide of tungsten
Wolioxip	W^2O	20	Tungstic acid
Wolisuliptriadia	W^3S^2	32	Bisulphuret of tung.
Wolisuli	WS	12	Trisulphuret of tung.
Wolichloriptria	W^3Cl	33	Chlorides.—a
Wolichlori	WCl	17	b
Wolichlorintria	WCl^3	35	c
——			SALTS:—
Kaliwolioxi	KWO	22	Tungstate of potash
Kaliwolintriaoxin	KW^3O^2	42	Bitungstate of potash
Calciwolintriaoxin	CaW^3O^2	37	Tungstate of lime
Kaliwulintriaflurin	KW^3F^2	43	Fluotungstate of potash

The tungstic acid combines with tungstates, in the same manner as silicic acid with silicates. Thus the bitungstates are WOW + KOW.

Bori.	B.	1	Boron.
Borioxip	B^2O	6	Dry boracic acid
Borisuli	BS	5	Sulphuret of boron
Borisulin	BS^2	9	Bisulphuret of boron
Borisulioxin	BSO^2	13	Sulphuric acid—boracid acid
Borichlori	BCl	10	Chloride of boron
Borifluri	BF	5·5	Fluoride of boron
———			SALTS :—
Hydroborioxi	HBO	5·25	Crystallised Boracic acid = HOB
Hydroborioxi Diatetratria	$H^2B^4O^3$	16·5	Ignited do. = HOB + HOB + BOB
Natiborinpentaoxintria	NB^5O^3	23	Borax (dry) = NOB + BOB + BOB
Natiborioxi Diatetratria	$N^2B^4O^3$	28	Basic borate of soda = NOB + NOB + BOB
Magiborintriaoxin	MgB^3O^2	14	Magnesia = MgOB + BOB
Ammihydroborinoxin	$AmHB^2O^2$	14·75	Ammonia = AmOB + HOB
			Fluo-borate :—
Kaliborintriaflurintetra	KB^3F^4	31	—of potash (after Berzelius)?

Cari.	C.	3	Carbon.
Carioxiptetratria	C^4O^3	24	Mellitic acid, dry
Carioxi	CO	7	Carbonic oxide
Carioxin	CO^2	11	Carbonic acid
Carisulintetra	CS^4	19	Sulphuret of Carbon
Carizoti	CZ	6·5	Cyanogen
Carizotisulin	CZS^2	14·5	Sulphocyanogen
Carichlori	CCl	12	Chloride of Carbon a.
Carichlorin	CCl^2	21	b. liquid
Carichlorintria	CCl^3	30	c. solid
Carichlorinoxi	CCl^2O	25	Phosgen gas
———			SALTS :—
Kalicarinoxin	KC^2O^2	24	Mellate of potash
Kalicaripoxintria	K_2CO^3	35	Carbonate of potash
Kalihydrocarioxintria	$KHCO^3$	25·25	Bicarbonate of potash

Kalicarioxin	KCO^2	21	Oxalate of potash
Kalihydrocarinoxintetra	KHC^2O^4	32·25	Binoxalate of potash
Kalicarisulin	KCS^2	21	Bisulphocarbonate of potassium
Kalicarizoti	KCZ	16·5	Cyanide of potassium
Kaliferipearintriazotintria	$K^2FeC^3Z^3$	46·5	Cyanide of potassium and Iron
Kalicarizotioxi	$KCZO$	20 5	Cyanate of potash
Kalicarizotisulin	$KCZS^2$	24 5	Sulphocyanide of potassium
Stibi.	Sb.	11	Antimony. Stibium.
Stibioxip	Sb^2O	26	Oxide of Antimony
Stibioxiptetratria	Sb^4O^3	56	Antimonious Acid
Stibioxi	SbO	15	Antimonic Acid
Stibisuli	SbS	15	Sulphurets:—a. Lead Grey
Stibisuli	SbS	15	b. Kermes Mineral
Stibisulindiatria	Sb^2S^3	34	c. Yellow Sulphuret
Stibisulintriapenta	Sb^3S^5	53	d. Golden Sulphur
Stibisulioxi Hexatetramona	Sb^6S^4O	86	Red Antimony Ore
Stibisulioxi Triatetramona	Sb^3S^4O	53	Crocus Antimonii
Stibichlori	$SbCl$	20	Chlorides:—a. Butter of Antimony
Stibichlorintriapenta	Sb^3Cl^5	78	—— b.
Stibiodisuli	$SbIS$	47	Iodide of Sulphuret of Antimony
——			SALTS, *according to Berzelius*:—
Kalistibioxi Diahexapenta	$K^2Sb^6O^5$	106	Antimonites:— a. (potash)
Kalistibioxi Diadodecaenna	$K^2Sb^{12}O^9$	188	b. do.
Kalistibioxi Monatriatria	KSb^3O^3	55	Antimoniates:— a. do.
Kalistibioxi Monahexahepta	KSb^6O^7	104	b. do.

Teli.	Te.	8	Tellurium.
Telioxip	Te^2O	20	Oxide of Tellurium
Telisuli	TeS	12	Sulphuret of do. *by Klaproth*
Telisulin	TeS^3	16	do. *by Davy*
Telisulioxin	$TeSO^3$	20	Sulphate of Tellurium
Telichlori	TeCl	17	Chloride of Tellurium
			SALTS :—
Kalitelioxi	KTeO	22	Tellurate of Potash
Kalihydrotelinoxin	$KHTe^2O^2$	34·25	Bitellurate of Potash
Kalitelisulin	$KTeS^2$	26	Sulpho-Tellurate of Potassium

Tani.	Ta.	15.	Tantalum.
Tanioxiptria	Ta_3O	49	Oxide of Tantalum
Tanioxip	Ta^2O	34	Tantalic Acid
Tanisuli	TaS	19	Sulphuret of Tantalum
Tanichlori	TaCl	24	Chloride of Tantalum
Tanifluri	TaF	19·5	Fluoride of Tantalum
			SALTS :—
Natitanioxi	NTaO	25	Tantalate of Soda
			Double Salts :—
Kalitaninflurintria	KTa_2F_3	53 5	Fluotantalate of Potash
Hydrotaninflurintria	HTa^2F^3	43·75	Hydrofluotantalic Acid

Titi.	Ti.	3	Titanium.
Titioxip	Ti^2O	10	Titanic acid, dry
Titisuli	TiS	7	Sulphuret of titanium
Titichlori	TiCh	12	Chloride of titanium
Titifluri	TiF	?	Fluoride of titanium
			SALTS :—
Hydrotitioxi	HTiO	7·25	Hydrate of titanic acid
Kalititioxi	KTiO	17	Titanate of potash
			Double Fluorides :—
Kalititinflurintria	KTi^2F^3	29·5	Fluorido of titan. 2 Fluoride of potas. 1

Sili.	Si.	2	Silicium.
Silioxip	Si^2O	8	Silica
Silisuli	SiS	6	Sulphuret of silicium
Silichlori	$SiCl$	11	Chloride of silicium
Silifluri	SiF	6·5	Fluoride of silicium
———			SALTS :—
Kalisilinflurintria	KSi^2F^3	27·5	Fluosilicate of potassium
Kalisilioxi	$KSiO$	16	Silicate of potash, a.
Kalisilintriaoxin	KSi^3O^2	24	Double silicate, b.
Kalisilioxi Diatetratria	$K^2Si^4O^3$	40	Triple silicate, c.

These are the varieties of silicates which, according to BERZELIUS, are so constituted, that the atoms of oxygen in the acid and the base bear to each other the relation of I to 1 (in *a*), 2 to 1 (in *c*), and 3 to 1 (in *b*). See my views of the constitution of the silicates in "Chemical Recreations," page 109—111.—In every silicate the atoms of oxygen form a third of the total number of elementary atoms present in the compound; then there is the same number of atoms of silicium, and lastly the same number of atoms of some other element, the presence of which gives the distinctive character to the silicate.

EXAMPLES :—			
Silioxip	Si_2O	8	Silica, dry, SiOSi
Hydrosilioxi	$HSiO$	6·25	Silica, hydrate, HOSi
Kalisilioxi	$KSiO$	16	Silicate of potash KOSi
Kalisilintriaoxin	KSi^3O^2	24	Double SiOSi + KOSi
Kalisilioxi Diatetratria	$K_2Si^4O^3$	40	Triple KOSi + SiOSi + KOSi
Ammisilioxi	$AmSiO$	10·5	Silicate of ammonia
Alisilioxi	$AlSiO$	8·25	Nephelin
Natialisilioxi Monadecaendecaendeca	$NAl^{10}Si^{11}O^{11}$	94 5	Electric schorl
Kalialisilioxi Monatriadodecaocta	$KAl^3Si^{12}O^8$	72 75	Feldspar, according to Berzelius
	$KAl^4Si^{17}O^{11}$	97	— , another analysis

	$KAl^5Si^{16}O^{11}$	97·25	Feldspar, another analysis
	$K^2Al^5Si^{13}O^{10}$	97·25	Leucite
Calcimagisilioximonaheptaoctaoctaaquintria	$CaMg^7Si^8O^8Aq^3$	87·5	Serpentine

A note given at page 154 of "Chemical Recreations" is not sufficiently explicit. If we admit the accuracy of Berzelius's account of feldspar, i. e. that the potassium and aluminum bear the same relation to each other as in alum, and that the oxygen presumed to be combined with these metals is equal to one-third of the quantity presumed to be combined with the silicium; then, I grant, alum must result from an exchange of the silicium for sulphur.

But a point of great importance, which this method of stating the question throws entirely into the shade, is, that the quantity of sulphur demanded for the production of alum by the given proportions of potassium, aluminum, and oxygen is 4 atoms, while the quantity of silicium which it displaces is 12 atoms. This is a mighty difference, and fully warrants my denial of the accuracy of Berzelius's statement, from which we should infer that alum and feldspar are, atom to atom, the same. According to his latest views, an atom of feldspar contains 1 atom of silicate of potash and 1 atom of trisilicate of alumina. According to my views, it contains 4 atoms of silicate of silica, 3 atoms of silicate of alumina, and 1 atom of silicate of potash; in all, 8 atoms. Some of the analyses of feldspar give 11 simple silicates, two of which analyses I have quoted above. It may be objected to my method of stating the constitution of the silicates, that it gives rise to the supposition of too many proximate constituents; but to this it may be replied, that, in consequence of its admission of very many proximate constituents, it enables one to understand the composition of many minerals, which, on any other theory, are a complete puzzle.

Every siliceous mineral, therefore, contains as many silicates as there are atoms of oxygen, and, in each, every atom of oxygen is accompanied by two positive atoms.

	Hydro.	H.	0·25	Hydrogen.
O	Hydroxip	H^2O	4·5	Water
	Hydroxi	HO	4·25	Peroxide of hydrogen
S	Hydrosuli	HS	4·25	Sulphuretted hydrogen
	Hydrosulin	HS^2	8·25	Bisulphuretted hydrogen
	Hydrosulioxin	HSO^2	12·25	Sulphuric acid, hydrate
	Hydrosulioxi	HSO	8·25	Hyposulphurous acid, hydrate
	Hydrosulinoxintria	HS^2O^3	20·25	Hyposulphuric acid, hydrate
	Hydrosulipoxintria	H^2SO^3	16·5	Oxygenated sulphuric acid
Z	Hydrozotiptria	H^3Z	4·25	Ammonia
	Ammonium	H^4Z	4·5	Ammonium (imaginary)
	Hydrozotioxintria	HZO^3	15·75	Nitric acid, hydrate
	Hydrozotioxin	HZO^2	11·75	Hyponitrous acid, hydrate
Cl	Hydrochlori	HCl	9·25	Muriatic acid
	Hydrochlorioxintria	$HClO^3$	21.25	Chloric acid, hydrate
	Hydrochlorioxintetra	$HClO^4$	25·25	Perchloric acid, hydrate
Bm	Hydrobromi	HBm	20·25	Hydrobromic acid
	Hydrobromioxintria	$HBmO^3$	32·25	Bromic acid, hydrate
I	Hydriodi	HI	32·25	Hydriodic acid
	Hydriodioxintria	HIO^3	44·25	Iodic acid, hydrate
F	Hydrofluri	HF	4·75	Hydrofluoric acid
P	Hydrophosip	H^2P	4·5	Phosphuretted hydrogen
	Hydrophosiptriadia	H^3P^2	8·75	Ditto
	Hydrophosinoxi	HP^2O	12·25	Hydrate of hypophosphorous acid
	Hydrophosinoxin	HP^2O^2	16·25	Hydrate of phosphorous acid

	Hydrophosioxin	HPO^2	12·25	Hydrate of phosphoric acid
Se	Hydroseli	HSe	10·25	Seleniuretted hydrogen
	Hydroselioxin	$HSeO^2$	18·25	Hydrate of selenic acid
As	Hydroarsiptriadia	H^3As^2	19·75	Arseniuretted hydrogen
Cr	Hydrochromioxin	$HCrO^2$	15·25	Chromic acid, hydrate
V	Hydrovanioxin	HVO^2	25·25	Vanadic acid, hydrate
Mo	Hydromolioxin	$HMoO^2$	20·25	Molybdic acid, hydrate
B	Hydroborioxi	HBO	5·25	Boracic acid, hydrate
	Hydroborintriaflurintetra	HB^3F^4	21·25	Hydrofluoboric acid
C	Hydrocariptetra	H^4C	4·	Gas of marshes
	Hydrocarip	H^2C	3·5	Olefiant gas
	Hydrocari	HC	3·25	Bicarburet of hydrogen
	Hydrocarioxin	HCO^2	11·25	Oxalic acid, hydrate
	Hydrocarinoxin	HC^2O^2	14·25	Mellitic acid, hydrate
	Hydrocarizoti	HCZ	6·75	Prussic acid
	Hydrocarizotioxi	$HCZO$	10·75	Cyanous acid
	Hydrocarizotisulin	$HCZS^2$	14·75	Sulphocyanic acid
	Hydrocaripchlori	H^2CCl	12·5	Hydrocarburet of chlorine
Te	Hydroteli	HTe	8·25	Telluretted hydrogen
	Hydrotelioxi	$HTeO$	12·25	Hydrate of telluric oxide
Ta	Hydrotanioxi	$HTaO$	19·25	Hydrate of tantalic acid
	Hydrotaninflurintria	HTa^2F^3	43·75	Hydrofluotantalic acid
Ti	Hydrotitioxi	$HTiO$	7·25	Titanic acid, hydrate
Si	Hydrosilioxi	$HSiO$	6·25	Silicic acid, hydrate
	Hydrosilinflurintria	HSi^2F^3	17·75	Hydrofluosilicic acid
	Hydrosiliboriflurioxi	$HSiBFO$	11·75	Hydrofluosilicate of boracic acid

SALTS :—

When SALTS are produced by the combination of the above *acids* with electro-positive *metals*, one atom of hydrogen always gives place to one atom of metal. Thus:

$HCl + K$ produces $KCl + H$,
$HSO^2 + K$ produces $KSO^2 + H$,
$HCZ + K$ produces $KCZ + H$,
$HSiO + K$ produces $KSiO + H$.

The statement that *water is decomposed* when iron is dissolved in diluted oil of vitriol, is a mere assumption, without a shadow of evidence in support of it, and made without necessity or utility.

Osmi.	Os.	12·5	Osmium.
Reckoned from the Symbols in Berzelius's Jahres-Bericht, 1829, which, however, are not very intelligible.			
			Oxides,
Osmioxiptetra	Os^4O	54	a
Osmioxiptria	Os^3O	41½	b
Osmioxipoctatria	Os^8O_3	112	c
Osmioxip	Os^2O	29	d
Osmioxiptetratria	Os^4O_3	62	e
Osmioxi	$Os\,O$	16½	f
			Sulphurets,
Osmisulip	Os^2S	29	a
Osmisuliptriadia	Os^3S^2	45½	b
Osmisuliptetratria	Os^4S^3	62	c
Osmisuli	$Os\,S$	16½	d
Osmisulintetrapenta	Os^4S^5	70	e
Osmisulindiatria	Os^2S^3	37	f
Osmisulin	$Os\,S^2$	20½	g
Osmichlorip	Os^2Cl	34	Chlorides a
Osmichloriptetratria	Os^4Cl^3	77	b
Osmichlori	$Os\,Cl$	21½	c
Osmichlorindiatria	Os_2Cl^3	52	d
Kaliosmipchlorintria	KOs^2Cl^3	62	Osmi-chloride of Potassium
Auri.	Au.	16·5	Gold. Aurum.
Aurioxip	Au^2O	37	Peroxide of Gold
Aurisuli	AuS	20·5	Sulphuret of Gold
Aurisulintria	AuS^3	28·5	Persulphuret

Aurichloriptria	Au_3Cl	58·5	Chloride of Gold
Aurichlori	$AuCl$	25 5	Perchloride of Gold
Auriodiptria	Au_3I	81·5	Iodide of Gold
Auricarizoti	$AuCZ$	23·	Cyanide of Gold
Auricarisulin	$AuCS^2$	27·5	Bisulpho Carbonate
———			SALTS:—
Kaliaurioxi	$KAuO$	30·5	Aurate of potash
Staniaurioxi	$SnAuO$	35·	Aurate of Tin (precipitate of Cassius.)
Kaliaurinchlorintria	KAu^2Cl^3	70·	Potassium-Chloride
Natiaurinchlorintria	NAu^2Cl^3	66·	Sodium-Chloride
Iri.	Ir.	12·25	Iridium.
Reckoned from the Symbols in Berzelius's Jahres-Bericht, 1829.			
Irioxiptetra	Ir^4O	53	Oxides:—a
Irioxipoctatria	Ir^8O^3	110	b
Irioxiptetratria	Ir^4O^3	61	c
Irisulioxin	$IrSO_2$	24¼	Sulphate of Iridium
Irichlorip	Ir^2Cl	33½	Chlorides a
Irichloripoctatria	Ir^8Cl^3	125	b
Irichlori	$IrCl$	21¼	c
Irichlorindiatria	Ir^2Cl^3	51½	d
Iricari	IrC	15¼	Carburet of Iridium
Kaliirinchlorin	KIr^2Cl^2	52	Double Chlorides, a
Kaliirichlori Diatetrapenta	$K^2Ir^4Cl^5$	114	b
Kaliirinchlorintria	KIr_2Cl^3	61½	c
Kaliirinchlorintetra	KIr^2Cl^4	70½	d
Rhodi.	R.	6·5	Rhodium.
Reckoned from the Symbols in Berzelius's Jahres-Bericht, 1829.			
Rhodioxiptetra	R^4O	30	Oxide, a.
Rhodioxiptria	R^3O	23½	b.
Rhodioxipoctatria	R^8O^3	64	c.
Rhodisulipoctatria.	R^8S^3	64	Sulphuret

Rhodichloripocta-penta	R^8Cl^5	97	Chloride:—a.
Rhodichlorip	R^2Cl	22	——— b.
			Double Chlorides:—
Kalirhodichlori Dia-tetrapenta	$K^2R^4Cl^5$	91	Potassium and rhodium.
Natirhodichlori Triatetrahexa.	$N^3R^4Cl^6$	98	Sodium and rhodium.
Plati.	Pt.	12·25	Platinum.
			Oxides:—
Platioxipocta	Pt^8O	102	Cooper's Black Oxide
Platioxiptetra	Pt^4O	53	Berzelius's Grey Protoxide
Platioxiptria	Pt^3O	40¾	Davy's Grey Oxide
Platioxip	Pt^2O	28½	Black Peroxide
			Sulphurets:—
Platisulip	Pt^2S	28½	Protosulphuret
Platisuli	PtS	16¼	Persulphuret
Platisulioxin	$PtSO^2$	24¼	Sulphate of Peroxide
Platichlorip	Pt^2Cl	33½	Protochloride
Platichlori	$PtCl$	21¼	Perchloride
Platicarisulin	$PtCS^2$	23¼	Bisulpho-Carbonate
			Double Chlorides:—
Ammiplatichlorin	$AmPtCl^2$	34¾	Protoch. of Pt. and Ammonium
Ammiplatinchlorin-tria	$AmPt^2Cl^3$	56	Perchloride of do.
Natiplatichlorin	$NPtCl^2$	36¼	Protoch. of Pt. and Sodium
Natiplatinchlorintria	NPt^2Cl^3	57½	Perchloride of do.
Kaliplatichlorin	$KPtCl^2$	40¼	Protoch. of Pt. and Potassium
Kaliplatinchlorintria	KPt^2Cl^3	61½	Perchloride of Do.
Kaliplatisulin	$KPtS^2$	30¼	Double Sulphuret of Pt. and Potassium
			Platinum Salts:—
Kaliplatioxi	$KPtO$	26¼	Platinum Oxide-potash
Ammiplatioxi	$AmPtO$	20¾	Platinum Oxide-ammonia.

Palli.	Pd.	6·5	Palladium.
Pallioxiptetra	Pd^4O	30	Oxides:—a.
Pallioxip	Pd^2O	17	b.
Pallisulip	Pd^2S	17	Sulphuret of Palladium
Kalipallinchlorintria	KPd^2Cl^3	50	Double Chloride of Palladium and Potassium
Kallipallinchlorin	KPd^2Cl^2	41	Do.
Meri.	Mr.	25	Mercury.
Merioxiptetra	Mr^4O	104	Black oxide
Merioxip	Mr^2O	54	Red oxide
Merisulip	Mr^2S	54	Protosulphuret
Merisuli	MrS	29	Sulphuret
Merisulioxin	$MrSO^2$	37	Persulphate
Merichlorip	Mr^2Cl	59	Protochloride, Calomel
Merichlori	$MrCl$	34	Perchloride, Cor. Sub.
Meriodip	Mr^2I	82	Protoiodide, yellow
Meriodi	MrI	57	Periodide, scarlet
Meribromip	Mr^2Bm	70	Protobromide
Meribromi	$MrBm$	45	Perbromide
Mericarizoti	$MrCZ$	31½	Cyanide of Mercury
Argi.	Ag.	27·5	Silver. Argentum.
Argioxip	Ag^2O	59	Oxide of silver
Argioxi	AgO	31·5	Peroxide of silver
Argisuli	AgS	31·5	Sulphuret of silver
Argisulioxi	$AgSO$	35·5	Hyposulphite of silver
Argisulioxin	$AgSO^2$	39·5	Sulphate of silver
Argisulinoxintria Aqui	AgS^2O^3 Aq	52	Hyposulphate of silver, cryst.
Argizotioxintria	$AgZO^3$	43	Nitrate of silver
Argichlori	$AgCl$	36·5	Chloride of silver
Argibromi	$AgBm$	47·5	Bromide of silver
Argiodi	AgI	59·5	Iodide of silver
Argifluri	AgF	32	Fluoride of silver
Argiselip	Ag^2S	65	Seleniuret of silver
Argiseli	AgS	37·5	Bisseleniuret of silver
Argichromioxin	$AgCrO^2$	42·5	Chromate of silver

Argimoli	$AgMo$	39·5	Molybdenum alloy
Argimolioxin	$AgMoO^{2}$	47·5	Molybdate of silver
Argimolisulintetra	$AgMoS^{4}$	55 5	Sulphomolybdate of silver
Argimolisulinpenta	$AgMoS^{5}$	59·5	Hypersulphomolybdate
Argiwolioxi	$AgWO$	39·5	Tungstate of silver
Argicaripoxintria	$Ag^{2}CO^{3}$	70	Carbonate of silver
Argicarizoti	$AgCZ$	34	Cyanide of silver
Argicarizotioxi	$AgCZO$	38	Howard's Fulminating silver
Ammiargioxi	$AmAgO$	36	Berthollet's Fulminating silver
Argicarizotisulin	$AgCZS^{2}$	42	Sulphocyanide of silver
Argicarisulin	$AgCS^{2}$	38·5	Sulphocarbonate of silver
Argistibi	$AgSb$	38·5	Antimonial silver ore
Argistibisulin	$AgSbS^{2}$	46·5	Rothgiltigerz
Ammiargipsulintriaoxintria	$Am^{2}AgS^{3}O^{3}$	60 5	Hyposulphite of silver and ammonia
Argimeri	$AgMr$	52·5	Silver amalgam, native
Cupri.	Cu.	8.	Copper. Cuprum.
Cuprioxiptetra	$Cu^{4}O$	36	Red oxide of copper
Cuprioxip	$Cu^{2}O$	20	Black oxide of copper
Cuprioxi	CuO	12	Thenard's Hyperoxide
Cuprisulip	$Cu^{2}S$	20	Sulphuret of copper
Cuprisuli	CuS	12	Bisulphuret of copper
Cuprisulioxin	$CuSO^{2}$	20	Sulphate of copper
Cuprizotioxintria	$CuZO^{3}$	23·5	Nitrate of copper
Cuprichlorip	$Cu^{2}Cl$	25	Protochloride of copper
Cuprichlori	$CuCl$	17	Perchloride of copper
Cupriarsip	$Cu^{2}As$	25·5	Tombac. White copper
Cupricarizoti	$CuCZ$	14·5	Cyanide of copper
Uri.	U.	35	Uranium.
Urioxiptria	$U^{3}O$	109	Protoxide of Uranium Peroxide of U. (unknown)

Urizotioxintria	UZO^3	50·5	Persesquinitrate of Uranium
Urisulioxin	USO^2	47	Persesquisulphate of Uranium
Uricarioxin	UCO^2	46	Peroxalate of Uranium
			URANIATES :—
Plumiurioxi Pentatriatetra	$Pl^5U^3O^4$	251	Uraniate of Lead ?
Bariurioxi	$BaUO$	56·5	Uraniate of Barytes
			DOUBLE SALTS :—
Kaliurichlorin	$KUCl^2$	63	Thomson's Potash-Muriate of Uranium
Kaliurisulioxi Diatriapentadeca	$K^2U^3S^5O^{10}$	185	Thomson's Potash-Sulphate of Uranium ?
Bisi.	Bi.	18	Bismuth.
Bisioxip	Bi^2O	40	Oxide of Bismuth
Bisisuli	BiS	22	Sulphuret of Bismuth
Bisisulin	BiS^2	26	Bisulphuret of Bismuth
Bisisulioxin	$BiSO^2$	30	Sulphate of Bismuth
Bisisuliptriaoxintria	Bi^3SO_3	70	Bisulphate of Bismuth
Bisizotioxintria	$BiZO_3$	33·5	Nitrate of Bismuth
Bisichlori	$BiCl$	27	Chloride of Bismuth
Bisihydroxi	$BiHO$	22¼	Hydrate of Bismuth
Stanni.	Sn.	14·5	Tin. Stannum.
Stannioxip	Sn_2O	33	Dark grey protoxide
Stannioxi	SnO	18·5	Yellow peroxide
Stannisuli	SnS	18·5	Sulphuret of Tin
Stannisulindiatria	Sn^2S^3	41	Sesquisulphuret. *Berzelius*
Stannisulin	SnS^2	22·5	Aurum musivum
Stannisulioxin	$SnSO^2$	26·5	Protosulphate of Tin
Stannichlori	$SnCl$	23·5	Protochloride of Tin
Stannichlorin	$SnCl_2$	32·5	Perchloride of Tin
Stannioxi Aquip	$SnO + {}_2Aq$	41·5	Hydrate of Peroxide
Stannioxi Aqui	$SnOAq$	23	Ditto

Plumi.	Pb.	26	Lead. Plumbum.
Plumioxip	$Pb^{2}O$	56	Yellow Oxide of Lead
Plumioxiptriadia	$Pb^{3}O^{2}$	86	Orange Oxide of Lead
Plumioxiptetratria	$Pb^{4}O^{3}$	116	Red Oxide of Lead
Plumioxi	PbO	30	Brown Oxide of Lead
Plumisuli	PbS	30	Sulphuret of Lead
Plumisulinpenta	PbS^{5}	46	do.
Plumisulioxi Diadiatria	$Pb^{2}S^{2}O^{3}$	72	Sulphite of Lead
Plumisulioxin	$PbSO^{2}$	38	Sulphate of Lead
Plumizotioxin	$PbZO^{2}$	37·5	Hyponitrite of Lead
Plumizotioxintria	$PbZO^{3}$	41·5	Nitrate of Lead
Plumichlori	$PbCl$	35	Chloride of Lead
Plumiodi	PbI	58	Iodide of Lead
Plumiseli	$PbSe$	36	Seleniuret of Lead
Plumichromioxin	$PbCrO^{2}$	41	Chromate of Lead
Plumimolioxin	$PbMoO^{2}$	46	Molybdate of Lead
Plumimolisulintetra	$PbMoS^{4}$	54	Sulphomolybdate of Lead
Plumimolisulinpenta	$PbMoS^{5}$	58	Hypersulphomolybdate of Lead
Plumicaripoxintria	$Pb^{2}CO^{3}$	67	Carbonate of Lead
Plumicarizoti	$PbCZ$	32·5	Cyanide of Lead
Ceri.	**Ce.**	**11·5**	**Cerium.**
			Protoxide (unknown)
Cerioxiptriadia	$Ce^{3}O^{2}$	42·5	Oxide-Oxydul. ?
Cerioxiptetratria	$Ce^{4}O^{3}$	58	Peroxide of Cerium
Cerisuli	CeS	15·5	Sulphuret of Cerium
Cerisulioxin	$CeSO^{3}$	23·5	Sulphate of protoxide of Cerium
Cerichlori	$CeCl$	20·5	Chloride of Cerium
Cerihydroxi	$CeHO$	15·75	Hydrate of protoxide of Cerium
Cobi.	**Co.**	**7**	**Cobalt.**
Cobioxip	$Co^{2}O$	18	Protoxide of Cobalt
Cobioxiptetratria	$Co^{4}O^{3}$	40	Peroxide of Cobalt

Cobisuli	CoS	11	Sulphuret of Cobalt
Cobisulindiatria	Co^2S^3	26	Sesquisulphuret of Co.
Cobisulin	CoS^2	15	Bisulphuret of Cobalt
Cobisulioxin	$CoSO^2$	19	Sulphate of Cobalt
Cobizotioxintria	$CoZO^3$	22·5	Nitrate of Cobalt
Cobichlori	$CoCl$	16	Chloride of Cobalt
Cobicaripoxintria	Co^2CO^3	29	Carbonate of Cobalt
Cobihydroxi	$CoHO$	11·25	Hydrate of Cobalt
Nicki.	Ni.	7	Nickel.
Nickioxip	Ni^2O	18	Protoxide of Nickel
Nickioxiptetratria	Ni^4O^3	40	Peroxide of Nickel
Nickisuli	NiS	11	Sulphuret of Nickel
Nickisulip	Ni^2S	18	Disulphuret of Nickel
Nickisulioxin	$NiSO^2$	19	Sulphate of Nickel
Nickizotioxintria	$NiZO^3$	22·5	Nitrate of Nickel
Nickichlori	$NiCl$	16	Chloride of Nickel
Nickihydroxi	$NiHO$	11·25	Hydrate of Nickel
Feri.	Fe.	7	Iron. Ferrum.
Ferioxip	Fe^2O	18	Protoxide of Iron
Ferioxiptriadia	Fe^3O^2	29	Black Oxide of Iron
Ferioxiptetratria	Fe^4O^3	40	Red Oxide of Iron
Ferisulipocta	Fe^8S	60	Sulphuret of Iron
Ferisulip	Fe^2S	18	Sulphuret of Iron
Ferisuli	FeS	11	Sulphuret of Iron
Ferisulinheptaocta	Fe^7S^8	81	Magnetic Pyrites
Ferisulindiatria	Fe^2S^3	26	Sulphuret of Iron
Ferisulin	FeS^2	15	Iron Pyrites
Ferisulioxin	$FeSO^2$	19	Protosulphate of Iron
Ferichlori	$FeCl$	16	Protochloride of Iron
Ferichlorindiatria	Fe^2Cl^3	41	Perchloride of Iron
Ferifluri	FeF	11·5	Fluoride of Iron
Ferifluri ndiatria	Fe^2F^3	27·5	Perfluoride of Iron
Feriphosip	Fe^2P	18	Phosphuret of Iron
Fericaripoxintria	Fe^2CO^3	29	Carbonate of Iron

Cadi.	Cd.	14	Cadmium.
Cadioxip	Cd^2O	32	Oxide of Cadmium
Cadisuli	CdS	18	Sulphuret of Cadmium
Cadisulioxin	$CdSO^2$	26	Sulphate of Cadmium
Cadizotioxintria	$CdZO^3$	29·5	Nitrate of Cadmium
Cadichlori	$CdCl$	23	Chloride of Cadmium
Cadiodi	CdI	46	Iodide of Cadmium
Cadimolioxin	$CdMoO^2$	34	Molybdate of Cadmium
Cadimolisulintetra	$CdMoS^4$	42	Sulphomolybdate of Cadmium
Cadimolisulinpenta	$CdMoS^5$	46	Hypersulphomolybdate of Cadmium
Cadicaripoxintria	Cd^2CO^3	43	Carbonate of Cadmium
Cadihydroxi	$CdHO$	18·25	Hydrate of Oxide of Cadmium
Cadiplati	$CdPt$	26·25	Alloy with Platinum
Zinki.	Zn.	8	Zinc.
Zinkioxip	Zn^2O	20	Oxide of Zinc
Zinkisuli	ZnS	12	Sulphuret of Zinc
Zinkisulioxin	$ZnSO^2$	20	Sulphate of Zinc
Zinkizotioxintria	$ZnZO^3$	23·5	Nitrate of Zinc
Zinkichlori	$ZnCl$	17	Chloride of Zinc
Zinkiodi	ZnI	40	Iodide of Zinc
Zinkiseli	$ZnSe$	18	Seleniuret of Zinc
Zinkimolioxin	$ZnMoO^2$	28	Molybdate of Zinc
Zinkimolisulintetra	$ZnMoS^4$	36	Sulphomolybdate of Zinc
Zinkicaripoxintria	Zn^2CO^3	31	Carbonate of Zinc
Zinkicarizoti	$ZnCZ$	14·5	Cyanide of Zinc
Zinkihydroxi	$ZnHO$	12·25	Hydrate of Oxide of Zinc
Mani.	Mn.	7	Manganese.
			Oxides of Manganese:—
Manioxip	Mn^2O	18	Green Protoxide
Manioxiptriadia	Mn^3O^2	29	Red Oxyd-Oxydul.
Manioxiptetratria	Mn^4O^3	40	Brown Deutoxide

Manioxi	MnO	11	Black Peroxide
Manisuli	MnS	11	Sulphuret of Manganese
Manisulioxi Tetradiamona	$Mn^4S^2O^1$	40	Oxy-sulphuret of do.
Manisulioxin	$MnSO^2$	19	Sulphate of do.
Manizotioxintria	$MnZO^3$	22·5	Nitrate of Manganese
Manichlori	$MnCl$	16	Chloride of Manganese
Manichlorindiapenta	Mn^2Cl^5	59	Perchloride of do.
Maniflurindiapenta	Mn^2F^5	36·5	Fluoride of do.
Manicaripoxintria	Mn^2CO^3	29	Carbonate of do.
Manisilioxi	$MnSiO$	13	Silicate of do.
			Hydrates :—
Manihydroxi	$MnHO$	11·25	*a.* White Hydrate of Protoxide, the mineral Varvicite
Manihydripoxin	Mn^2HO^2	22·25	*b.* Hydrate of Deutoxide, the mineral manganite or Glanzmangan
Manihydripoxintria	Mn^2HO^3	26·25	*c.* Manganesic Acid in crystals *Fromherz*
Manihydroxi Triadiatetra	$Mn^3H^2O^4$	37·5	*d.* Hydrate of Peroxide, Berthier's Analysis
Manihydroxi Diadiatria	$Mn^2H^2O^3$	26·5	*e.* Hydrate of Peroxide, Forchhammer's Analysis
Thori.	$Th.$	15	Thorium.
Thorioxip	Th^2O	34	Thoria
Thorisuli	ThS	19	Sulphuret of Thorium
Thorisulioxin	$ThSO^2$	27	Sulphate of Thoria
Thorichlori	$ThCl$	24	Chloride of Thorium
Thorihydroxi	$ThHO$	19¼	Hydrate of Thoria
Kalithorisulinoxintetra	$KThS^2O^4$	49	Double Sulphate of Thoria and Potash
Ziri.	$Zr.$	5·5	Zirconium.
Zirioxip	Zr^2O	15	Zirconia
Zirisuli	ZrS	9·5	Sulphuret of Zirconium

Zirisulioxin	$ZrSO^2$	17·5	Sulphate of Zirconium
Zirizotioxintria	$ZrZO^3$.	21	Nitrate of Zirconium
Zirichlori	$ZrCl$	14·5	Chloride of Zirconium
Ziricaripoxintria	Zr^2CO^3	26	Carbonate of Zirconia
———			*Double Fluorides* :—
Kalizirinflurintria	KZr^2F^3	34·5	Potassium and Zirconium
Kalizirifluri Diatriapenta	$K^2Zr^3F^5$	59	ditto
Ali.	Al.	2·25	Aluminum.
Alioxip	Al^2O	8·5	Alumina
Alisulioxin	$AlSO^2$	14·25	Sulphate of Alumina
Alizotioxintria	$AlZO^3$	17 75	Nitrate of Alumina
Alichlori	$AlCl$	11·25	Chloride of Aluminum
Alihydroxi	$AlHO$	6·5	Hydrate of Alumina
Yttri.	Y.	8	Yttrium.
Yttrioxip	Y^2O	20	Yttria
Yttrisulioxin	YSO^2	20	Sulphate of Yttria
Yttrizotioxintria	YZO^3	23·5	Nitrate of Yttria
Yttricaripoxintria	Y^2CO^3	31	Carbonate of Yttria
Yttrihydroxi	YHO	12·25	Hydrate of Yttria
Beri.	Be.	4·5	Glucinum. Beryllium.
Berioxip	Be^2O	13	Glucina
Berisulioxin	$BeSO^2$	16·5	Sulphate of Glucina
Berichlori	$BeCl$	13 5	Chloride of Glucinum
Berisilioxi	$BeSiO$	10·5	Silicate of Glucina
			Emerald or Beryl :—
Berialisilioxi Monadiaennahexa	$Be^1Al^2Si^9O^6$	51	$\begin{cases} 1\ BeSiO \\ 2\ AlSiO \\ 3\ Si^2O \end{cases}$ Berzelius's formula for this mineral is $\dddot{Be}Be\dddot{Si}^4 + 2\ Al\dddot{Al}\dddot{Si}^2$ $(GS^4 + 2\,AS^2)$ which is equal to $Be^2Al^4Si^8O^{33}$.

Magi.	Mg.	3	Magnesium.
Magioxip	Mg^2O	10	Magnesia
Magisuli	MgS	7	Sulphuret of magnesi.
Magisulioxin	$MgSO^2$	15	Sulphate of magnesia
Magizotioxintria	$MgZO^3$	18·5	Nitrate of magnesia
Magichlori	$MgCl$	12	Chloride of magnesium
Magichlorioxintria	$MgClO^3$	24	Chlorate of magnesia
Magichromioxin	$MgCrO^2$	18	Chromate of magnesia
Magimolioxin	$MgMoO^2$	23	Molybdate of magnesia
Magiwolioxi	$MgWO$	15	Tungstate of magnesia
Magicaripoxintria	Mg^2CO^3	21	Carbonate of magnesia
Magicarioxin	$MgCO^2$	14	Oxalate of magnesia
Magisilioxi	$MgSiO$	9	Silicate of magnesia
Magihydroxi	$MgHO$	7·25	Hydrate of magnesia

Ammi.	Am.	4·5	Ammonium. { Hydro. 1 Azote, 3·5
Ammisuli	AmS	8·5	Hydrosulphuret of ammonia
Ammisulioxin	$AmSO^2$	16·5	Sulphate of ammonia
Ammizotioxintria	$AmZO^3$	20	Nitrate of ammonia
Ammichlori	$AmCl$	13·5	Sal ammoniac
Ammichlorioxintria	$AmClO^3$	25·5	Chlorate of ammonia
Ammibromi	$AmBm$	24·5	Bromide of ammonium
Ammiodi	AmI	36·5	Iodide of ammonium
Ammifluri	AmF	9	Fluoride of ammonium
Ammimolioxin	$AmMoO^2$	24·5	Molybdate of ammoni.
Ammimolisulintetra	$AmMoS^4$	32·5	Sulfomolybdate of am.
Ammiwolioxi	$AmWO$	16·5	Tungstate of ammoni.
Ammicaripoxintria	Am^2CO^3	24	Carbonate of ammonia
Ammicarioxin	$AmCO^2$	15·5	Oxalate of ammonia
Ammicarisulin	$AmCS^2$	15·5	Sulphocarbonate of ammonia
Ammicarizotisulin	$AmCZS^2$	19	Sulphocyanide of am.
Ammialintria-sulintetraoxinocta Aquindodeca	$AmAl^3S^4O^8Aq^{12}$	113·25	Ammonia Alum, crystallised
Ammiargioxi	$AmAgO$	36	Fulminating silver. Berthollet

Calci.	Ca.	5	Calcium.
Calcioxip	Ca^2O	14	Lime
Calcisuli	CaS	9	Sulphuret of Calcium
Calcisulioxin	$CaSO^2$	17	Sulphate of lime
Calcisulioxin Aqui	$CaSO^2Aq$	21·5	Alabaster. Gypsum
Calcizotioxintria	$CaZO^3$	20·5	Nitrate of lime
Calcichlori	$CaCl$	14	Chloride of Calcium
Calcichlorioxintria	$CaClO^3$	26	Chlorate of lime
Calcifluri	CaF	9·5	Fluoride of Calcium
Calcicaripoxintria	Ca^2CO^3	25	Carbonate of lime
Calcicarioxin	$CaCO^2$	16	Oxalate of lime
Calcihydroxi	$CaHO$	9·25	Hydrate of lime
Stroni.	Sr.	11.	Strontium.
Stronioxip	Sr^2O	26	Strontian
Stronisuli	SrS	15	Sulphuret of strontium
Stronisulioxin	$SrSO^2$	23	Sulphate of strontian
Stronizotioxintria	$SrZO^3$	26·5	Nitrate of strontian
Stronichlori	$SrCl$	20	Chloride of strontium
Stronichlorioxintria	$SrClO^3$	32	Chlorate of strontian
Stronifluri	SrF	15·5	Fluoride of strontium
Stronicaripoxintria	Sr^2CO^3	37	Carbonate of strontian
Stronicarioxin	$SrCO^2$	22	Oxalate of strontian
Stronyhydroxi	$SrHO$	15·25	Hydrate of strontian
Bari.	Ba.	17·5	Barium.
Barioxip	Ba^2O	39	Barytes
Barioxi	BaO	21·5	Peroxide of barium
Barisuli	BaS	21·5	Sulphuret of barium
Barisulioxin	$BaSO^2$	29·5	Sulphate of barytes
Barizotioxintria	$BaZO^3$	33	Nitrate of barytes
Barichlori	$BaCl$	26·5	Chloride of barium
Barichlorioxintria	$BaClO^3$	38·5	Chlorate of barytes
Bariodi	BaI	49·5	Iodide of barium
Barifluri	BaF	22	Fluoride of barium
Barichromioxin	$BaCrO^2$	32·5	Chromate of barytes
Bariborintriafluringtetra Aqui	BaB_3F^4 Aq	43	Fluoborate of barytes

Baricaripoxintria	Ba^2CO^3	50	Carbonate of barytes
Baricarioxin	$BaCO^2$	28·5	Oxalate of barytes
Barihydroxi	$BaHO$	22	Hydrate of barytes
Liti.	L.	1·5	Lithium.
Litioxip	L^2O	7	Lithium
Litisuli	LS	5·5	Sulphuret of lithium
Litisulioxin	LSO^2	13·5	Sulphate of lithia
Litizotioxintria	LZO^3	17	Nitrate of lithia
Litichlori	LCl	10·5	Chloride of lithium
Liticaripoxintria	L^2CO^3	18	Carbonate of Lithia
Litihydroxi	LHO	6	Hydrate of lithia
Nati.	N.	6.	Sodium. Natrium.
Natioxip	N^2O	16	Protoxide of sodium
Natioxiptetratria	N^4O^3	36	Peroxide of sodium
Natisuli	NS	10	Sulphuret of sodium
Natisulioxin	NSO^2	18	Sulphate of soda
Natizotioxintria	NZO^3	21·5	Nitrate of soda
Natichlori	NCl	15	Chloride of sodium
Natichlorioxintria	$NClO^3$	27	Chlorate of soda
Natibromi	NBm	26	Bromide of sodium
Natiodi	NI	38	Iodide of sodium
Natifluri	NF	10·5	Fluoride of sodium
Natiborinpentaoxintria	NB^5O^3	23	Borate of soda, borax
Naticaripoxintria	N^2CO^3	27	Carbonate of soda
Natihydrocarioxintria	$NHCO^3$	21·25	Bicarbonate of soda
Natihydrocarioxi Tetradiatriaema	$N^4H^2C^3O^9$	69·5	Sesquicarbonate of soda !
Natihydroxi	NHO	10 25	Hydrate of soda
Natisilioxi	$NSiO$	12	Silicate of soda
Kali.	K.	10.	Potassium. Kalium.
Kalioxip	K^2O	24	Protoxide of potassium
Kalioxindiatria	K^2O^3	32	Peroxide of potassium
Kalisuli	KS	14	Sulphuret of potassium

Kalisulin	KS^2	18	2nd Sulphuret
Kalisulintria	KS^3	22	3rd do.
Kalisulintetra	KS^4	26	4th do.
Kalisulinpenta	KS^5	30	5th do.
Kalisulioxin	KSO^2	22	Sulphate of potash
Kalizotioxintria	KZO^3	25·5	Nitrate of potash
Kalizotioxin	KZO^2	21·5	Hyponitrite of potash
Kalichlori	KCl	19	Chloride of potassium
Katichlorioxintria	$KClO^3$	31	Chlorate of potash
Kalibromi	KBm	30	Bromide of potassium
Kalibromioxintria	$KBmO^3$	42	Bromate of potash
Kaliodi	KI	42	Iodide of potassium
Kaliodioxintria	KIO^3	54	Iodate of potash
Kalifluri	KF	14·5	Fluoride of potassium
Kalichromioxin	$KCrO^2$	25	Chromate of potash
Kalicarinoxin	KC^2O^2	24	Mellate of potash
Kalicaripoxintria	K^2CO^3	35	Carbonate of potash
Kalihydrocarioxintria	$KHCO^3$	25·25	Bicarbonate of potash
Kalicarioxin	KCO^2	21	Oxalate of potash
Kalicarizoti	KCZ	16·5	Cyanide of potassium
Kalicarizotioxi	$KCZO$	20·5	Cyanate of potash
Kalicarisulin	KCS^2	21	Bisulphocarbonate of potash
Kalicarizotisulin	$KCZS^2$	24·5	Sulphocyanide of potassium
Kalisilioxi	$KSiO$	16	Silicate of potash
Kalihydroxi	KHO	14·25	Hydrate of potash
Kalihydrosulin	KHS^2	18·25	Hydrosulphuret of potassium
Kalihydrosulinoxintetra	KHS^2O^4	34·35	Bisulphate of potash
Kaliplatinchlorintria	KPt^2Cl^3	61·5	Chloride of potash and platinum
Kaliferipcarintriazotintria	$K^2FeC^3Z^3$	46·5	Yellow cyanide of iron and potassium
KalifericarizotiTriadiahexahexa	$K^3Fe^2C^6Z^6$	83	Red cyanide of iron and potassium
Kalimanioxin	$KMnO^2$	25	Manganesate of potash
Kalialintriasulintetraoxinocta	$KAl^3S^4O^8$	64·75	Alum
Kalialintriasulintetraoxinocta Aquindodeca	$KAl^3S^4O^8+Aq^{12}$	118·75	Crystallised alum

AMUSING EXPERIMENTS.

THE object of this section is to present a series of experiments calculated to render the student familiar not only with the operations described in the first part of this work, but with the chemical elements and preparations enumerated in part second. I have endeavoured to render these experiments as easy of performance as possible, and believe that the student will meet with few difficulties if he will take the trouble to observe three things:—I. To follow the instructions he finds here. II. Not to take too much in hand at once. III. Not to be in too great a hurry.

CHEMICAL METAMORPHOSES.

WHEN certain chemical bodies are placed in contact under particular circumstances, they combine together and produce new compounds possessed of new properties. These changes are evidenced to the eye by changes of colour and form, of taste and smell, of temperature and of bulk, which frequently are of a very surprising nature. I shall adduce a few experiments, in proof of these facts.

A beautiful green liquid produced by mixing a blue one with a colourless one.—Nearly fill a tall cylindrical glass with water, and add to it a spoonful of the tincture of cabbage. The mixture will be of a fine blue colour: next, add a few drops of colourless liquid ammonia, when the mixture will instantly become green. *Rationale.*—This experiment is designed to exhibit one of the distinguishing properties of alcalies, namely, that of changing vegetable colours. (See the article on *Neutralisation*, page 23.) A solution of potash or soda produces the same effect as liquid ammonia; but, if the liquid made green by ammonia be boiled, it regains its blue colour; because the alcali, being volatile, is driven off in the gaseous state by the heat.—The following experiment shows the mode of using the common *test for alcalies.*

Into a test glass of water, pour a few drops of an alcaline solution, and then dip into the mixture a slip of turmeric paper. The pale yellow colour of the test-paper will be changed to a deep brown.

If you make these experiments for your own satisfaction, you may make them in very small glass tubes, about the following size. If you show them to others, you must use larger vessels, that the effects may be easily perceived. The glasses depicted at pages 23, 24, 25, 30, are adapted for these experiments.

To produce a beautiful crimson liquid by mixing a blue one and a colourless one.—To a mixture of a tea-spoonful of tincture of cabbage with a glassful of water, add a few drops of sulphuric or muriatic acid; upon which, the blue colour given by the tincture will be changed to red.—This is designed to show the influence of acids in changing vegetable colours. See page 23. If a red colour is produce by dropping a little tincture of cabbage into a certain solution, we know that that solution contains an acid; and if the reddened solution upon being heated becomes blue, we learn that the acid is either carbonic acid, or sulphuretted hydrogen—as only those two acids are readily expelled from solution by heat.

To change the colour of a liquid from green to red, by adding a colourless one to it.—The green liquid alluded to is one produced by adding a few drops of liquid ammonia to diluted tincture of blue cabbage. The colour of it is changed to red by pouring a little sulphuric acid into it. A portion of the acid neutralises the alcali by combining with it, and another portion produces its ordinary reddening effect. See page 23.

To make the same liquid alternately red and green by the addition of two colourless liquids, you have only to add alternately a few drops of sulphuric acid and liquid ammonia, to diluted tincture of cabbage.

A liquor which is crimson at the bottom, purple in the middle, and green at the top.—Nearly fill a tall cylindrical glass with water, and colour it blue by adding a table-spoonful of tincture of cabbage—then make it green at the top by gently adding a little liquid ammonia, and afterwards pour a little sulphuric acid gently down the inner side of the glass, or through a funnel with a neck long enough to reach the bottom of the vessel; upon which the effect above mentioned will be produced. If you stir the mixture with a glass rod, it will be blue, green, or red, according to the predominance of one or other of the ingredients. See page 24. If you add a little liquid chlorine, the colour is totally destroyed, and the liquid turns white.

Three different colours produced from the same vegetable infusion, by the addition of three colourless liquids.—Into each of three test glasses put a little diluted blue tincture of cabbage. To one, add a solution of alum, to the second, a little solution of potass, and to the third, a few drops of muriatic acid. The product of the first mixture will have a purple colour, that of the second, a bright green, and that of the third, a beautiful crimson.

A beautiful blue liquid produced by mixing two colourless ones.—Add a few drops of a solution of nitrate of copper to a glass of water—the mixture will be colourless if sufficiently dilute: pour a little liquid ammonia into it—the mixture will then assume a fine deep blue colour.—*Rationale.* The alcali precipitates the copper, and then re-dissolves it, forming a blue liquid.

To produce a colourless liquid by mixing a deep blue one with a colourless one.—Add a little nitric acid to the blue liquid produced in the preceding experiment: upon which the colour instantly disappears.—*Rationale.* The blue compound is decomposed, and nitrate of ammonia and nitrate of copper are formed. These salts remain in solution in the water, the quantity of which renders the blue colour of the cupreous salt insensible.

Coloured liquors which become colourless on the addition of a colourless liquor.—A solution of chlorine in water, or a solution of chloride of lime, deprives all solutions of vegetables of their colour.

ACTION OF ACIDS AND ALCALIES ON A VARIETY OF VEGETABLE COLOURS.—These experiments may be performed in wine glasses or small test tubes.

1. *Alkanet digested in alcohol.*—A red liquor. Alcalies turn it blue.

2. *Bilberries infused in water.*—A violet liquor. Alcalies turn it green.

3. *Brazil wood.*—Boiled in 16 times its weight of water. A deeply coloured red liquor. Alcalies turn it purple or violet. Iron salts turn it brown. Caustic potash in 200,000 parts of water acts upon it. Strong acids make it bright rose red. Sulphuric acid has the most powerful action. The acid red liquor is a fine colour for prints on paper, but it is apt to injure the paper. Sulphurous acid bleaches it. Some of the weaker acids turn it yellow.

4. *Paper saturated with Indigo dissolved in sulphuric acid.* Chlorine bleaches it. Boiling nitric acid does the same. Chromates and bromides bleach it cold. Iodides do the same, but leave a red stain on the paper that gradually disappears in the air.

5. *Litmus.*—Solution in water or alcohol. Blue. Acids redden it. Alcalies restore the blue colour.

6. *Rhubarb* infused in water. A bright yellow solution. Alcalies turn it reddish-brown. Very readily affected.

7. *Rose leaves* macerated in alcohol. Yellowish-brown liquid. Alcalies turn it green, acids make it rose-red. The

changes of colour in this solution are effected by an exceedingly small portion either of acid or alcali.

8. *Turmeric.*—Infusion in water, or tincture in alcohol. Yellow liquids. Alcalies turn them reddish-brown.

9. *Violets.*—A violet liquor. Alcalies turn it green and acids red.

10. *Logwood.*—Gives a brownish solution. Acids render it yellow or reddish. Alcalies give it a splendid purple colour. If a drop of a solution of logwood and another of liquid of ammonia are put on the same plate, but at a distance from each other, the vapour of the alcali very soon changes the colour of the logwood.

See more upon this subject at page 122.

CHEMICAL MIRACLE! *Two limpid liquors converted by mixture into a solid mass.—Process* 1. If a saturated solution of chloride of calcium be mixed with a saturated solution of carbonate of potash, both of which are transparent liquids, the result is the formation of an opaque and almost solid mass.—*Rationale.* Mutual decomposition of the salts takes place—chloride of potassium, and carbonate of lime are formed; and the latter absorbs the whole of the water of solution, and thus a degree of solidity is produced.—*Process* 2. Drop sulphuric acid into a saturated solution of chloride of calcium; in this case also an opaque mass is produced.—*Rationale.* The chloride is decomposed, and sulphate of lime, a highly insoluble salt, is formed.—*Process* 3. Pour a saturated solution of caustic potass into a saturated solution of sulphate of magnesia (Epsom salt), a nearly solid mass is again produced.—*Rationale.* The sulphuric acid leaves the magnesia (which then combines with water and is precipitated in the form of a white powder) in order to combine with the potash. — If a little nitric acid be added to the product of *process* 1, the solid mass will be converted into a transparent liquid: the insoluble carbonate of lime being converted into the soluble nitrate of lime.

To dissolve metallic copper in a liquid.—Put a farthing or a bit of copper wire into a glass of water, and add a small quantity of aqua fortis or nitric acid. An effervescence will be produced, much pungent red vapour (nitrous acid gas, page 75) will be formed in the air, and the water will assume a dirty green colour. The red vapour is not disengaged from the liquid, though it forms just above it in the glass. A colourless gas is actually set free, but this is acted upon by the air of the atmosphere so as to produce the red gas. Finally, the copper disappears and the liquor becomes blue. A little dirt remains at the bottom, and may be separated by filtration (page 27). The filtered liquor is *a solution of nitrate of copper* (page 137), which salt may be separated by crystallisation (page 21).

To dissolve iron in a liquid.—Iron can be dissolved in a mixture of oil of vitriol and water (page 96), and the solution on evaporation, gives green crystals of sulphate of iron.

To dissolve silver in a liquid.—See nitrate of silver, page 132.

To dissolve gold in a liquid.—See page 129.

THE CHAMELEON SPIRIT.—*A liquid which is blue when the bottle containing it is open, but colourless when the bottle is closed.*—Put some shreds of clean copper into a small phial, fill it with liquid ammonia, and cork it air-tight. Nothing will take place. Open the bottle, and let it remain for a few hours. The liquid will become blue. Cork the phial —after some time, the liquid will be colourless. Re-open the phial,—the liquid will become blue again.—It will be found necessary, sometimes, to add to the mixture, after it has remained exposed to the air for some time, a little more copper.—*Rationale.* Metallic copper is not acted upon by ammonia; but if the copper is allowed to attract oxygen from the air, it then becomes soluble. But copper oxidised only so much as to render it soluble produces a colourless solution; and it is only when it is highly oxidised that the *blue* solution is produced. Thus, in the above case, the copper, when the phial was left open, acquired enough of oxygen from the atmosphere to produce blue solution. When, however, the phial was closed, the blue colour disappeared—why?—because the remainder of the metallic copper took, in order to render *it* soluble, the super-abundant oxygen from the portion of copper which was dissolved. The blue colour returned, when the bottle was opened, because more oxygen was attracted.

THE MINERAL CHAMELEON.—*Experiment* 1. A few grains of this compound put into a wine glassful of water produce a *green* colour; an increase of the quantity changes the colour to a *blue;* more still to a *purple;* and a yet further increase produces a beautiful *deep purple.*—*Experiment* 2.

Put equal quantities of this substance into two separate wine-glasses, and add to the one *hot*, and to the other *cold*, water. The hot solution will be of a beautiful green colour; the cold one of a deep purple. By using more glasses, and water more or less in quantity, and at different temperatures, a great variety of colours will be produced in this way from the same substance. See page 183.

A solid white powder produced by mixing two colourless liquids.—This is an effect of common occurrence in chemical experiments. See the article on *Precipitation*, page 29. The solids produced by the mixture of different liquids are of every variety of colour and form, and it is a very amusing and instructive exercise to examine the effect of various precipitating agents on different metallic solutions. I shall add an example in the *test for muriatic acid.*—Add a drop of muriatic acid to a quart of water; pour some of the mixture into a test glass, and let fall into it a single drop of a solution of nitrate of silver—the whole will instantly be pervaded by a milkiness, as the chlorine of the muriatic acid combines with the silver and forms chloride of silver, a salt highly insoluble. So great is the power of this test, that if a single grain of common salt is dissolved in 42,250 grains of water, the muriatic acid is detected, though amounting to only the 1-108,333 part of the weight of the solution.

A fluid produced by rubbing together two solid metals.—Triturate an amalgam of lead with an amalgam of bismuth—the product will be fluid, like mercury. Fluids are likewise produced when any of the mixtures which follow are triturated: acetate of lead and sulphate of zinc—or, sulphate of soda and nitrate of ammonia—or, sulphate of soda and carbonate of potash.—These salts should be all fresh crystallised.

A green coloured solid produced by mixing a blue one with a white one.—Triturate crystallised sulphate of copper with crystallised super acetate of lead. In this process, acetate of copper (which is of a green colour) is formed.

To make a beautiful solid green paint by mixing a blue liquor with a colourless liquor.—Add to a hot solution of blue sulphate of copper, a little solution of colourless carbonate of soda—a beautiful powder (known by the name of French Green) will be precipitated.—The powder is a sub-carbonate of copper. The liquor may be separated by filtration.

Two pungent and invisible gases unite and form an inodorous solid.—Process 1. Fill a jar with ammoniacal gas, in the manner described at page 52, and another with muriatic acid gas, as described at page 51. Apply the two jars mouth to mouth, and the above mentioned effect will instantly be produced, chloride of ammonium being formed and precipitated on the sides of the jars.—*Process* 2. Dip a clean feather into muriatic acid, and moisten with it the interior of a glass such as depicted at page 276, and in like manner moisten the interior of a similar glass with liquid ammonia. The glasses, in this state, will seem empty, but if they be put mouth to mouth together, the whole included space will be filled with a dense white vapour; which in the end settles on the sides of the glasses in the form of a white powder, solid chloride of ammonium.—*Process* 3. If two jars, one containing ammoniacal gas, and the other containing carbonic acid gas, are thus put together, solid carbonate of ammonia will be formed.

Two highly odorous liquids produce a mixture totally without odour.—Mix liquid ammonia with muriatic or nitric acid, till the resulting liquor is neutral (page 23). The smell of both the ingredients disappears, and the saline product has neither the acid nor the alcaline taste possessed by the two odorous liquids.

Two bodies devoid of odour produce a compound highly odorous and volatile.—Mingle together in a mortar equal parts of sal ammoniac and quicklime. The mixture disengages ammoniacal gas, which has a very pungent odour (page 99).

To deprive a red rose of its colour and to restore the colour again.—Hold a red rose over the blue flame produced by burning sulphur. You can do this by fastening the rose to the top of the inverted glass jar. This flame diffuses a gas which has the property of depriving vegetables of their colour. It is called sulphurous acid gas. Whenever it comes into contact with the rose, the colour is so discharged as to make the rose either beautifully variegated or entirely white. If you afterwards dip the rose into water, its red colour is restored to it.

A substance which may be eaten, produced by the admix-

ture of two powerful poisons.—A solution of muriatic acid and a solution of caustic soda are both poisonous. If mixed together, they produce a solution of common kitchen salt. —*Explanation.* 9½ parts of muriatic acid contain 9 parts of chlorine and ¼ part of hydrogen. 10¼ parts of caustic soda contain 6 parts of sodium, 4 parts of oxygen, and ¼ part of hydrogen. When these quantities of the ingredients, in a state of aqueous solution, are mingled together, new combinations take place. 9 parts of chlorine and 6 parts of sodium, produce 15 parts of common salt, also called chloride of sodium; and 4 parts of oxygen and ½ part of hydrogen, produce 4½ parts of pure water. Thus nothing is lost or left at liberty. The chloride of sodium dissolves in the water at the moment of formation, but can be extracted by evaporation.

Two cold liquids, on being mixed together, produce a boiling-hot liquid; and the bulk of two liquids diminished by mixing them.—1. Take a small phial about half full of cold water; grasp it gently in the left hand, and from another phial pour sulphuric acid very gradually into the water. The mixture will immediately become so hot, that the phial cannot be held.—If a thin glass tube, three-eighths of an inch in diameter, containing a small quantity of water, be plunged into a mixture of one part water to four parts acid, the water in the tube will boil.—2. Take a long tube, with two bulbs and a stopper at top. Fill the tube and the lower bulb with sulphuric acid; then fill the upper bulb with water, put in the stopper, shake the apparatus to mix the liquids, and invert it quickly. You will see by the vacant space in the tube, how much the mixture diminishes in bulk.

The density of solid bodies is altered by chemical action.—If two cubical inches of copper, and the same bulk of tin, be melted together, they form an alloy of the size of only three cubical inches. One-fourth of their bulk, therefore, is lost, though they remain unaltered in weight.

SYMPATHETIC INKS.—Sympathetic inks are liquids which, being used for writing or drawing, form figures or letters which, under certain circumstances, or after certain operations, become changed in colour, or from being illegible become conspicuous. Liquids of this kind known at present are very numerous, and the experiments executed with their assistance are some of the most entertaining which modern chemistry affords. Several varieties were known in very ancient times. We find Ovid teaching young women to deceive their guardians by writing billets to their lovers with new milk, letters formed with which are rendered legible by coal-dust or soot. And Ausonius proposes the same thing to Paulinus. Pliny, in whose time it was known that any colourless, glutinous juice would attract black powder as well as milk, recommends for this purpose the milky sap of certain plants.

There are several metallic solutions, entirely colourless, or having a very weak tint, which, if applied to paper, produce figures that remain invisible, either till washed with another colourless solution, or exposed to its vapour. Among these, there is none more curious, or capable of exciting greater astonishment, than that which consists of a solution of sugar of lead, which becomes black on exposure to sulphuretted hydrogen gas, even at a considerable distance. The mountebank performers of mechanical tricks and chemical experiments, whom the people have been pleased to term conjurers, derive considerable aid from the service of bodies such as those under consideration. How potent must he appear to ignorant eyes, who causes a figure to grow, as it were, on a paper untouched by any hand, and exposed meanwhile to view! Yet, to do this, requires only that the person use the ink just named, and manage the business with a little dexterity.

Whatever is written with a solution of sugar of lead, with a clean pen, remains invisible while dry; but, when the writing is washed over with liquid sulphuretted hydrogen, it becomes instantly black. The most extraordinary circumstance is this, that, though sheets of paper without number, and even a board, be placed between the invisible writing and the reviving liquid, the same effect will take place as in the former case; the writing being turned black by a vapour which penetrates the substance of the wood and folds of the paper.

It is instructive to look back upon the hypotheses which successive speculators set up to explain the causes of various effects observed in nature. The phenomena which appeared to take place without any visible agency, were ascribed by the schoolmen to certain "occult qualities."

This doctrine gave way to the idea of magnetic effluvia, which was succeeded by a something termed sympathy; and sympathy itself was exploded by attraction and electricity. In future times our own method of tracing out causes will, no doubt, be reckoned as absurd as the ridiculous modes which have preceded it.

Another remarkable kind of sympathetic ink is that prepared from cobalt, the invention of which, though generally ascribed to Hellot, is affirmed by Pott to have been detailed by a German lady, very early in the seventeenth century. But it must be older than this, if it be true that, by means of this invention, Theophrastus Paracelsus could, in the same picture, represent alternately summer and winter. Such is the nature of this ink of cobalt, that the traces of it in writing or drawing are colourless when cold, but when moderately heated become of a beautiful green colour; which colour, however, vanishes as the paper cools, but can be made to reappear by a fresh application of heat.

I shall now mention a few of these inks out of the great number which but a slight acquaintance with chemistry will suggest to the student.—Note. The sympathetic inks may be laid on paper either with a camel-hair pencil or a common quill pen; but, whichever is used, it is necessary that the instrument be perfectly clean—the presence of the smallest conceivable quantity of any foreign body will go nigh to spoil the effect. The best thing to use is a clean fresh-cut pen.

1. Write with weak tincture of galls: the characters will be invisible. Moisten the paper with a feather dipped in a weak solution of sulphate of iron—the writing will become black. To understand this phenomenon, you have only to know that a black liquid commonly termed ink is formed by adding infusion of galls to a solution of sulphate of iron.

2. Write with a weak solution of prussiate of potash—the letters will be invisible. Moisten the paper, as in the preceding experiment, with a weak solution of sulphate of iron—the writing will assume a fine *blue* colour.—*Rationale.* Prussian blue is here formed.

3. Wash paper with a solution of sulphate of iron, and suffer it to dry: when written upon this paper, dilute solu-

tion of prussiate of potash produces *blue* letters, and tincture of galls *black* ones; but upon common paper, they make colourless marks.

4. Most acids, diluted and written with, leave marks which are invisible till the paper is heated, when they become *black;* the heat concentrating the weak acid, and enabling it to char the paper.

5. Write with a dilute solution of nitrate of silver, and let the writing dry *in the dark*—it will be invisible; fold up the paper so as to keep the writing in the dark—it will continue invisible; but, expose the writing to the light of the sun—it will become *black.*—*Rationale.* The nitrate of silver has the property of being decomposed by light; a black colour being acquired by the metallic oxide.

6. Characters written with a solution of equal parts of sulphate of copper and sal ammoniac, have a *yellow* colour when heated, but are invisible when cold.

7. Write with a dilute solution of chloride of copper. The writing is invisible when cold, but *yellow* when heated.

8. Write with a dilute solution of chloride of gold, and dry the writing in the dark—it will be invisible. Moisten the paper, by means of a feather or bit of sponge, with a solution of chloride of tin—the writing will then assume a purple colour, occasioned by the presence of a minute portion of the purple precipitate of Cassius, a compound of tin and gold.

9. Write with a solution of nitrate of bismuth—the writing will be invisible. Immerse the paper in water—the characters will then be legible.—*Rationale.* The water decomposes the salt, and causes a white compound of bismuth to be precipitated in a solid form.

10. Expose a paper upon which you have written with nitrate of bismuth, to the vapour of water impregnated with sulphuretted hydrogen—the writing will become black.—It is the property of bismuth to be thus affected by sulphuretted hydrogen. The black substance is sulphuret of bismuth.

11. Let a paper upon which you have written with nitrate of bismuth be moistened with solution of prussiate of potash—the writing will assume a beautiful *yellow* colour; cyanide of bismuth being formed.

12. Write with a solution of sulphate of copper—no

writing will be visible. Wash the paper with solution of prussiate of potash—the writing will then get a *reddish-brown* colour; cyanide of copper being formed.

13. Write with a solution of super-acetate of lead—the writing will be invisible. Hold the paper over a saucer containing liquid sulphuretted hydrogen—the writing will become, first black, and then glittering like silver.—The metallic salt is here decomposed by the sulphuretted hydrogen, which produces black sulphuret of lead.

14. Upon a fire-screen let there be drawn a representation of winter, with trees destitute of foliage, and ground covered with snow. Let, however, every part of the picture which, if the scene represented summer, would be green, be covered with the sympathetic ink, produced by dissolving zaffre or impure cobalt in aqua regia, which is a mixture of nitric and muriatic acids. Draw, for instance, leaves on the trees, and grass on the ground. These marks will not be visible; the picture will still bear the aspect of winter. But, let the fire-screen be placed for a short time near the fire, *then* the view will exhibit all the verdure of summer. When allowed to cool, the verdure disappears; but it may be again revived, by the same means as before, and that as often as is desired, provided the paper be not heated beyond a certain point; for, if heated too much, the ink will assume a permanent brown colour. You must understand that a solution of pure chloride of cobalt will not answer the above purpose, as it gives a blue and not a green sympathethic ink. The green tint is due to the presence of arsenic and iron among the impure cobalt.

EXPERIMENTS ON HEAT AND COLD.

There are four things which have considerable influence over chemical bodies and chemical processes. These four things are light, heat, electricity, and magnetism. By many chemists these things are called *imponderable bodies.* They use the term *imponderable* to signify that the bodies have no weight, or are incapable of being weighed, and the word *body* to signify that these four things have a material existence, or are composed of particles. But no one has ever been able to *prove* that light, heat, electricity, and magnetism, or any one of them, has a corporeal existence.

Consequently, their existence, *as bodies*, is merely imaginary; and all that we can safely say of the *nature* of these *things*, or powers, or principles, is, that we are ignorant of it.

All that we absolutely know of light, heat, electricity, and magnetism, relates to the influence of these things upon *material* bodies, that is to say, upon the chemical elements and their compounds. In other words, we only know these things by their *effects*, but of these effects, we know not the *causes*.

As it is impossible to treat systematically of every branch of chemistry in this little volume, I shall at present satisfy myself with giving a few unconnected experiments and observations on these subjects, referring the reader to more extensive works for fuller information.

HEAT AND COLD PRODUCED BY THE SAME LIQUID AT THE SAME TIME.—Put your right hand into a basin, containing water made as hot as you can well bear it, and put your left hand into a basin containing very cold water. After a few minutes, take out both hands, and instantly plunge them into water warmed moderately: what effect will be produced? The water will *cool your right hand* and *warm your left*.

Explanation of this experiment.—What we call *heat*, is the effect produced by some power of an unknown nature, to which power chemists sometimes give the name of *caloric*. *Cold* is a negative quality: it signifies the absence of heat, or rather, a diminution of heat. This producer of heat (caloric) always tends to an equilibrium; that is to say, heated bodies placed among cool ones, always part with their heat to the cool ones, till all are brought to the same temperature. Of course, by such a process, the cool bodies are heated, and the heated ones cooled. This doctrine of the distribution of heat enables us fully to comprehend the phenomenon of the above experiment. A hot hand put into cold water, communicates a part of its heat to that water, and thus becomes cooled. Again, a cold hand put into hot water, takes a portion of heat from that water, and consequently is heated. Hence we readily discover how water of a medium temperature heated the hand that had been cooled by cold water, and cooled the hand that had been heated by hot water.

People very generally imagine that the sensation of heat is an accurate test of temperature, and they are thereby frequently led to miscall things. They come into this room from the open air to-day, and exclaim, "How warm it is!" To-morrow, they will again come into it from a still warmer room, and will cry "How cold it is!" In the first case they gain heat, and therefore call the room warm; in the latter case they lose heat, and then they term it cold; while, in reality, the air of the room continues, during the whole time, heated precisely to the same degree of temperature.

Two men were travelling on a high mountain; one of them was ascending, the other descending it. About the middle they met. "Bless me!" exclaimed he who was going down, "how extremely hot it is to-day!" "Hot!" cried the other, "why, I never felt so cold in all my life." These two men judged from their sensations, and truly expressed what they felt. At the top of the mountain the air was cold; at the bottom of it the air was warm. He who was descending came, therefore, into warm air, and was heated; on the contrary, he who was ascending was, by coming to the cool air, cooled. We learn from this, that our sense of feeling can never inform us respecting the true temperature of the bodies by which we are surrounded.

HEAT EXPANDS BODIES, as the following experiments will prove.—*Process* 1. Take a piece of iron that exactly fits a ring made to receive it. Let it be made red-hot. It will be then so much enlarged in bulk, that it will not go into the ring.

Process 2.—Procure a long glass tube, with a bulb blown at one end; put into the bulb of this instrument some cold water or alcohol. Then, holding the tube in the hand, plunge the bulb into hot water: upon this, the enclosed liquid, as it gains heat from the hot water, will rise in the tube. The expansion will be seen more clearly, if the liquid in the bulb be coloured.

Process 3.—Let a bladder, partly filled with air, be tied at the neck, and held near a fire. The small quantity of air inclosed will speedily expand, and fill the bladder completely.

That, in all these cases, the expansion of the different bodies is really occasioned by heat, is very evident from the circumstance, that, when they become cool, they become small again.

Remarks on the phenomenon of expansion.—Of all the properties of heat, none is more remarkable than its power of expansion. Matter of every description, bodies in every state, are, by an accession of caloric, enlarged in bulk; and, on the contrary, when bodies are deprived of heat, they are reduced in bulk.

In order to account for so curious a phenomenon as increase of size by the addition of invisible matter, certain philosophers have supposed caloric to be a peculiar fluid, possessed of so subtile a nature, as to be capable of forcing itself between, and consequently of driving asunder, the particles of matter of even the very densest kind. And they imagine that it is by this means that it is able to overcome the attraction of cohesion, and thereby to dilate bodies.

The fact shown by process 1, is taken advantage of by coopers in fastening the staves of a cask with iron hoops: before the hoops are put on, they are heated, and of course enlarged; they then, on cooling, contract, and the cask is tightly bound.—The expansion of fluids (process 2) has been very usefully applied in the construction of thermometers, by which it is made the means of measuring the variations of temperature in other bodies.

A THERMOMETER, or *measurer of heat*, is a small tube of glass, with a bulb at the end of it; the bore of the tube is very small, and perfectly cylindrical; the bulb is entirely, and the tube partly, filled with the fluid by whose expansion the degrees of heat are to be measured. The tube is applied to a scale, formed on fixed principles, and the expansion of the fluid is thereby measured with accuracy. The fluid with which thermometers are generally filled is the metal mercury, *that* being found to combine more advantages than any other fluid. The *scale* just mentioned is divided into two hundred and twelve equal portions, which are called degrees; the two hundred and twelfth degree, usually written 212°, being the topmost one. The mark at the bottom of the scale, near the bulb (0°), is called *zero*.

When the thermometer is immersed in melting ice, the surface of the mercury stands invariably at the 32d degree, shortly said, at 32°, and this is on that account called the *freezing point of water*. When the thermometer is plunged into boiling water, the mercury rises to 212°, which, therefore, is called the *boiling point of water.* All bodies that are as hot as boiling water, make the mercury rise as high as boiling water does; and all bodies that are as cold as melting ice, or freezing water, make the mercury sink to 32°. If the thermometer is immersed in a mixture of equal parts of water at 32° and 212°, the mercury stands level with 122°; we have, in this case, an excellent illustration of what has been said regarding the tendency which heat has to an equilibrium: the hot water communicates 90° of heat to the cold, and its own temperature is thereby reduced 90°.

The thermometer does not tell the precise quantity of heat contained in the bodies it is applied to; it only shows by how many degrees of heat the temperature of certain substances exceeds that of others. For we cannot deprive any body of all the heat it contains. The mercury rises by abstracting heat, and falls by communicating it. If the mercury is sunk to 0° by being plunged into a certain mixture, still we cannot say that that mixture is deprived of heat, since it is evident, that the mercury fell upon giving out part of its heat to the mixture, and became stationary upon the production of an equilibrium. Though the lowest point on the thermometer scale is 0°, yet cold can be produced by many degrees more intense than that; so, also, can much greater heat than that of boiling water be produced. Thermometers for chemical purposes are sometimes marked to 600° above 0°, and to 40° below it; which marks show the boiling and freezing points of mercury.

We must now notice a very remarkable exception to the laws of expansion upon increase of heat. When water at 32° is heated, instead of expanding, as other bodies in the same situation would do, it becomes denser, continuing to do so, more and more, till it arrives at 40°, after which it regularly expands! When water at 212° is cooled, it contracts till it comes to 40°, and then it gradually expands till it comes to 32°! This property of water is a very beneficial one, as we shall presently see.

DIFFERENT BODIES EXPAND IN DIFFERENT DEGREES.—This may be proved by the following process:—Procure two glass tubes, each having a bulb at one end. Fill the bulb of one of the tubes with water, and that of the other with alcohol. The two liquids had better be coloured by some vegetable infusion. Now, take the two tubes, and plunge the bulbs together into hot water; both the liquids will expand and rise in the tubes, but the alcohol with far more rapidity than the water. The cause of the difference in the expansibility of bodies is unknown.

HEAT PASSES QUICKLY THROUGH SOME BODIES, SLOWLY THROUGH OTHERS.—All bodies through which heat passes are called *conductors* of it; those through which it passes quickly are termed *good* conductors, and those through which it passes slowly, *bad* conductors. Dense bodies are, in general, the best conductors; light, porous bodies, the worst. Bodies which are the worst conductors of heat, have the greatest capacity for it; that is to say, they take a greater quantity of heat than good conductors, to raise an equal bulk to a given thermometric temperature, within a certain time. When bodies are compressed, heat is evolved; because, as, by their condensation, their conducting powers are increased, so are their capacities for heat diminished. The following experiments *prove* the conducting powers of bodies to be different.

Process 1.—Take a rod of iron a foot long, and a rod of wood just the same size. Put one end of each into a fire, and hold the other extremities by the hands. When the one end of the iron has become red hot, the other end will be almost unbearably hot; but the wood will scarcely give any heat to the hand, though held till nearly all consumed by the fire. Hence we learn, that iron is a good conductor of heat, but wood a bad one.

Process 2.—Prepare a number of equally-sized rods of different substances, copper, lead, tin, iron, glass, bone, and wood of various sorts. Coat one end of each, by dipping it into melted wax or tallow. When they are all ready, plunge their uncoated extremities into boiling water, or hot sand: in a short time the wax or tallow will be melted; but it will be observed, that all the coatings do not melt together, but, that of each particular rod in the order of its power of conducting heat. The metallic rods (these, too, in their particular order) produce the effect first, next the glass, and last of all the wood.

CURIOUS MOTION PRODUCED IN LIQUIDS BY HEATING AND COOLING THEM.—Fill a large phial with water, and put into it a small quantity of powdered amber, having previously added to the water a sufficient quantity of potash to produce a solution having the same specific gravity as amber. Immerse the phial in a glass of hot water; upon which a very singular internal motion will be immediately perceived. A current of the fluid will rise up the sides of the phial, and another descend in the centre of it. Now take the phial out of the hot water, and observe the effects of its cooling. The currents will be reversed; the external one will descend, and the internal one ascend.—The use of the powdered amber is to make the opposite currents into which the water is thrown visible.

Rationale of this experiment.—The manner in which a quantity of water, put in a vessel over a fire, is heated throughout, is by the constant agitation of its particles; for though heat is transmitted from one particle of a fluid to another in the same manner as in solid bodies, yet it is only so in a very small degree. As the particles of water immediately at the bottom of a vessel are expanded by heat, they become, of course, specifically lighter than the rest of the fluid; and consequently rise to the surface, communicating, in their progress, part of their heat to the colder particles around them. Successive portions are thus heated at the bottom, and rise to the surface; and this agitation continues till all the liquid is brought to the greatest degree of heat it can acquire, namely, to its boiling point. If a liquid is heated at the surface, the heated particles being specifically lighter than those below, cannot descend, and therefore no agitation can be produced to communicate the heat to the bottom of the water. It was once asserted that heat could not descend, and in apparent proof of this, the upper surface of a vessel of water can be boiled and evaporated, while a cake of ice remains frozen at the bottom. But it has been proved that heat *is* propagated downwards, by transmission from particle to particle, though but slowly.

In the experiment just performed, the water rises at the sides; this is because the heat is communicated through the medium of the sides of the bottle. The descending current in the centre, is occasioned by the sinking of the water which parts with a portion of its heat, to the atmosphere, at the surface. When the fluid is held out of the water, the currents are reversed, because the external particles being in contact with cool air, are cooled; they therefore descend and force up the central particles, which are lighter because warmer.

From what has been said above, it will be conceived, that water in large quantities, as, for instance, in deep lakes, when cooled by the atmosphere in winter, sinks in successive portions, till the whole bulk of it is of the temperature of 40°; after which, as it cools to 32° (its freezing point), it continues unagitated, that is, its cool particles, being lighter than its warm ones, remain at the surface, and are at last converted into a sheet of ice. How manifest are the wisdom and goodness of the GREAT ARTIFICER of the world in this arrangement! If water continued to condense till it arrived at the temperature of 32°, the water on the surface of our rivers would sink as it froze, another sheet of water would freeze immediately, and sink also; the ultimate consequence of which would be, that the beds of our rivers would become depositories of immense masses of ice, which no subsequent summer could unbind; and the whole world would shortly be converted into a frozen chaos!

TO PROVE THAT WATER EXPANDS WHEN FREEZING.—Fill a small phial with water, cork it securely, and place it in a situation where the water contained in it may be frozen. Whenever solidification takes place the bottle will burst.

The force with which water expands when in the act of freezing is immense. A small brass globe, which would have required a force equal to 27,700 pounds to have burst it, has been bursted by the freezing of a little water in it. By the expansion of water during frosts, trees and rocks are often split asunder. Slate is dug from quarries in large blocks, which are placed, edge uppermost, exposed to the rain; this penetrates their fissures, and, when a frost takes place, expands, and splits the slate into thin layers.

TO SHOW THAT HOT WATER IS LIGHTER THAN COLD.—Pour gently hot water into a tall glass nearly filled with cold water; it will remain on the surface: but if cold water be poured upon hot water, it will sink to the bottom. This experiment may be rendered more striking by colouring that portion of water which is poured in.

To cause Water to Boil on the Surface of Ice.—To effect this, first freeze a quantity of water in the bottom of a long glass tube, closed at one end, either by exposure to cold air, or by means of a *freezing mixture* (of which we shall speak presently). Then cover the cake of ice by a quantity of water, and hold the tube (without handling the part of it containing the ice) in such a manner over a lamp, that the surface of the water may be heated to the point of boiling: for this, the tube requires to be placed in a diagonal direction, which is such as allows the water at the top of it to be heated, while the ice remains unheated below.

Sudden Conversion of a Liquid into an Invisible Fluid or Vapour, and re-conversion of it into a Liquid.—Procure a long and narrow glass tube, having a bulb at one end. Put into this instrument a tea spoonful of sulphuric ether, and then fill it (tube and all) with water. The water may be coloured by sulphate of indigo. Let the mouth of the tube (the bulb being turned upwards) be put into a vessel of water; it may be kept in this situation, by being fixed into a hole made in a little stool. Next pour boiling water gently upon the top of the ball: the sudden addition of heat will instantly change the ether into a vapour, which, by its expansion, forces the coloured water out of the vessel, and occupies its place. It is proper, however, not to allow the whole of the water to be forced out; but after expansion has proceeded to a certain degree, to pour then *cold* water upon the vessel. This will immediately re-convert the vapour of the ether into a liquid, and cause the water to rush up into the bulb, to supply the vacuum.

Rationale.—This experiment is intended to show that heat has great influence on the form or state of bodies. When solids are heated, they become liquids, as is proved in every instance of fusion; and when liquids are heated, they acquire the gaseous form, and become invisible elastic fluids, possessed of the mechanical properties of common air. They retain this form or state as long as their temperature remains sufficiently high, but re-assume the liquid form when cooled. Different fluids pass into the aeriform state at different temperatures: the temperature at which a liquid becomes changed into a vapour, is called its *boiling point.*

TO CAUSE WATER TO BOIL BY THE APPLICATION OF COLD, AND TO CEASE TO BOIL BY THE APPLICATION OF HEAT.—Provide a Florence flask, a good cork that fits it closely, and a piece of bladder, softened by having been soaked in water, Fill the flask half full of water, and place it over a lamp, till the water boils; then remove the flask, instantly cork it securely, and tie the moistened bladder over the neck and cork, so as to prevent the least access of air. The boiling of the water, which continues a little while after the flask is removed from the lamp, soon ceases entirely: but it will immediately recommence, if the flask is plunged into cold water; and cease again, when the flask is held near the fire.

The explanation of the experiment is this:—The boiling points of liquids are regulated by the pressure of the atmosphere. The greater the pressure, the greater is the degree of heat requisite for making the liquor boil; and, consequently, the degree of heat required to cause the ebullition of a liquid is small, under a small pressure.

Now, in what manner do these facts explain the curious phenomena of the above experiment? Why, when the flask was taken from the lamp, in order to be closed, the upper part of it was filled with vapour, the quantity of which was increased by that generated during the short time that the water continued to boil, after being removed from the lamp; and it was the great pressure of this body of vapour, which made the still hot water cease to boil. The boiling recommenced when the flask was cooled, because, by that cooling, the vapour was condensed into water, and a vacuum formed. This being the case, the water will boil at a very low temperature; and the heat that it retains is sufficient for the purpose. The boiling of the water ceased again, upon the flask being heated, because the vapour formed by that means renewed the pressure on its surface.

Sometimes Florence flasks are so thin, that, when the vapour is condensed, the glass is broken by the pressure of the atmosphere. The following is another mode of showing this experiment, calculated to obviate this inconvenience. Provide a six-ounce medicine phial, half fill it with water, and place it in a pan of boiling water over a fire, till the water it contains boils also. Then cork it closely. Place this phial, thus prepared, in a tea saucer; pour cold water upon it; when the water in the phial will boil—next, pour hot water upon it, when the water in the phial will cease to boil. The same experiment may be performed with a very small glass tube, having a bulb blown at the extremity, such as *b*, page 11.

TO FREEZE WATER BY PUTTING IT INTO A PAN ON THE FIRE.—Prepare a FREEZING MIXTURE, as directed below, and place the pan containing it over the fire; then immediately plunge into it a tube of thin glass, about three-eighths of an inch in diameter, containing a small quantity of water. In a short time, by the action of the freezing mixture, the water in the tube will be converted into ice.—Care must be taken not to let it remain too long, or the ice after being formed will be melted.

Rationale.—During the liquefaction of bodies, a quantity of heat is absorbed, which is essential to the state of liquidity, and which does not increase the sensible or thermometric temperature. The same may be observed of the conversion of liquids into vapours. Consequently, if a cold solid body, and the same body hot and in a liquid state, be mixed in known proportions, the temperature after mixture will not be the proportional mean, as would be the case if both were liquid, but will fall short of it—much of the heat of the liquid body being consumed in rendering the solid body *liquid* before it produces any effect upon its sensible temperature.

Equal parts of *water* at 32°, and of *water* at 212°, will produce, on mixture, a mean temperature of 122°. But equal parts of ice at 32°, and of water at 212°, will only produce (after the liquefaction of the ice) a temperature of 52°, the greater portion of the heat of the water being employed in thawing the ice, before it produces any rise of temperature in the mixture. Thus the water is cooled 160 degrees, while the ice is heated only 20; consequently 140 degrees of heat have disappeared, this having in fact united to the solid water (ice) to produce fluidity. Heat thus rendered insensible, or combined, is termed *latent heat.*

The same phenomena are observable in all cases of liquefaction, and we produce artificial cold, often of great intensity, by the rapid solution of certain saline bodies in water. Upon this principle, the action of freezing mixture depends.—In the above process, the water becomes solid, by giving out its *heat of fluidity* to the mixture.

TABLE OF FREEZING MIXTURES.

Mixtures.		Thermometer sinks.
Muriate of Ammonia .	5 parts	From 50° to 10°
Nitrate of Potash .	5	
Water . . .	16	
Nitrate of Ammonia .	1 part	From 50° to 4°
Water . . .	1	
Sulphate of Soda .	5 parts	From 50° to 3°
Diluted Sulphuric Acid	4	
Snow . . .	2 parts	From 32° to — 5°
Common Salt .	1	
Muriate of Lime, crys.	3 parts	From 32° to — 50°
Snow . . .	2	
Snow, or pounded Ice	12 parts	From + 18° to — 25°
Common Salt .	5	
Nitrate of Ammonia .	5	
Chloride of Calcium, cryst.	5 parts	From + 32° to — 40°
Snow . . .	4	
Diluted Sulphuric Acid	2 parts	From + 32° to — 23°
Snow . . .	3	

In order to produce the effects described in the above table, several things must be attended to. The salts employed must be fresh crystallised, and should contain as much water of crystallisation as possible; they should also be quite dry, and reduced to fine powder immediately before being used. The vessel in which the freezing mixture is made should be very thin; and the substance it is made of should be a good conductor of caloric. Tin vessels answer very well; but, when it is intended to put acid mixtures into them, they must be coated with wax. The materials should be mixed as quickly as possible, and must be in sufficient quantity to fill the vessel.—When great cold is to be produced, the materials for the mixture must first, separately, be reduced to the temperature marked in the table, by being placed in some of the other freezing mixtures; and they are then to be mixed together in a vessel placed in a similar freezing mixture.

Mercury freezes at —39°, so that, by the aid of some of the mixtures described in the above table, put together in the manner we have just directed, the interesting experiment of the congelation of this singular metal may be performed. The readiest method of exposing the mercury to the action of the mixture, is to place a little of it, either in a small glass tube, or on a watch glass, or concave piece of tin, supported in the middle of a pretty large mass of the freezing mixture.

To Freeze Water in a few minutes, even in the Midst of Summer.—Take a thin glass tube, four or five inches long, and two or three eighths of an inch in diameter. This must be closed at one end, and have water poured into it, to the height of an inch. Now, by means of the dropping tube or edulcorator, (page 32.) let a stream of sulphuric ether fall upon that part of the tube where the water is. The ether, as soon as exposed to the atmosphere, rapidly evaporates; but, in order to be converted into vapour, it requires a considerable quantity of caloric; and it therefore immediately robs the water in the tube of its heat of fluidity. The consequence is, that the water is changed to ice; and if a thin spiral wire be previously put into the tube, the ice will adhere to it, and may be drawn out.

Cold is produced in all cases of evaporation. The inhabitants of warm climates cool their liquors for drinking, by wrapping the vessels containing them in wet cloths, and hanging them up in the sun. The water in the cloth evaporates quickly, and thus produces cold. A person whose clothes are wet, feels cold even when near a fire; it is because the water, as it evaporates, robs his body of caloric.—Under certain circumstances, the cold produced by evaporation is very great, being even sufficient to freeze water. This has been proved by the above experiment; and is also most elegantly shown by that which follows.

Dr Wollaston's Cryophorus, or *Frost Bearer*.—This instrument is a glass tube of the fifth of an inch internal diameter, and about twelve inches long. At each end of this tube is a ball of one inch diameter, and the tube is bent to a right angle at the distance of half an inch from each ball. One of these balls should be somewhat less than half full of water, and the remaining cavity should be as perfect a vacuum as can readily be obtained; which is effected by making the water boil briskly in the one ball before sealing up the capillary opening left in the other ball. The cryophorus is employed to demonstrate the relation between evaporation at low temperatures, and the production of cold. To make use of it, prepare a freezing mixture, and plunge one of the balls into it; upon which, the water in the other ball will be frozen in a few minutes.

By referring to what has been said above, we see, that the instrument, as it was closed while the water in it was boiling, is filled with vapour. This vapour, when the ball is plunged in the freezing mixture, is condensed by the common operation of cold; and the vacuum produced by this condensation, gives opportunity for a fresh quantity of vapour to rise from the opposite ball. Now, the small quantity of water which rises to supply this vacuum, takes, in order to be converted into vapour, a large quantity of heat from the remainder of the water; and it is by the reduction of temperature thus effected, that the water is eventually changed into ice.

INSTANTANEOUS CRYSTALLISATION: A CURIOUS EXAMPLE OF THE PRODUCTION OF HEAT, BY THE CONVERSION OF A LIQUID INTO A SOLID.—Into two ounces of boiling water, put as much sulphate of soda, as it will dissolve (about three ounces). Pour as much of this saturated solution, when boiling hot. into a phial, as will nearly, but not quite, fill it; cork the phial closely, and let it stand to cool. When cold, the solution is still fluid; but the instant you draw the cork, a very beautiful, but confused crystallisation, of the whole mass, will immediately take place; and, at the same time, so much heat is evolved as to make the phial warm.

The explanation of the experiment is this: water will dissolve more sulphate of soda when hot than when cold; and cold water will dissolve more in proportion as the pressure of the atmosphere is diminished. The hot water was here saturated, and, had it been suffered to cool in an open vessel, would have deposited part of the salt. But, in this case, none was deposited, for by suffering the solution to cool in a close vessel, a partial vacuum was produced at the surface of it, (the steam which occupied the top part of the phial when the cork was inserted, being, by the subsequent cold, condensed,) and the water, when cold, was thus enabled to hold in solution, all the salt which, when hot, it had dissolved. As soon, however, as, by drawing the cork, you admitted the usual pressure of the atmosphere, the cold water was rendered incapable of holding so much salt in solution, and part was, therefore, instantly crystallised. The heat which was evolved, was the heat of liquidity of the portion of the salt which thus became solid. If, when the salt has crystallised, you plunge the phial containing it into hot water, it will be again dissolved. You may then cork the phial, as before, and the same solution will serve for a repetition of the experiment.

Curious effect of Colour with respect to the Absorption and Reflection of Heat.—Take 6 pieces of tin plate, each one inch square—paint (on one side only) 1 black, 1 blue, 1 green, 1 red, 1 yellow, and let the other remain bright. On the backs of these pieces of metal, lay a thin coat of cerate, composed of oil and wax, which easily melts. Place them, thus prepared, on a board painted white, and expose the coloured surfaces of the metal to the rays of the sun. The heat will melt the cerate, and (if the board rests in a proper position) it will run down—from the black, the blue, the green, the red, and the yellow pieces—while the bright one remains nearly unaffected.—This experiment shows that light-coloured surfaces reflect heat, and dark ones absorb it. Hence we learn, that, if we wish to be warmed by the sun, we should clothe ourselves in black; and that, in the summer, light-coloured dresses are preferable.

ILLUSTRATIONS OF GALVANISM.

Sketch of the Science of Galvanism.—1. It was accidentally discovered by Galvani, an Italian, that if the crural nerve and the muscles of the leg of a recently-killed frog be laid bare, and a piece of zinc be placed upon the nerve, and a piece of copper upon the muscle, and the two metals, while so placed, be made to touch each other, the leg of the frog is immediately thrown into violent convulsions. 2. Volta, a friend of Galvani's, invented the *pile* described below; and showed that shocks like those produced by electricity could be received from it.—3. Shortly after, it was found that water, and many other substances, could be decomposed by the galvanic energy.—4. It was next discovered, that when compound bodies are decomposed, oxygen and acids accumulate round the positive pole; while hydrogen, alcalies, earths, and metals, accumulate round the negative pole. Hence it came to be imagined, that chemical combination is identical with electrical attraction; and, that the reason that oxygen combines with hydrogen, and acid with alcalies, earths, and metals, is that they are in opposite states of electricity.—5. Galvanic electricity, when properly excited and directed, is sufficiently powerful to decompose any compound whatever. And even pure gold may be burned by being made to form a part of a galvanic circuit.

AN ECONOMICAL GALVANIC APPARATUS.—Obtain a number (say thirty) of the smooth old penny pieces, or of thin square or round pieces of copperplate; and the same quantity of plates of zinc of the same size. The pieces of zinc may be easily cast in a mould made of clay, for that metal is of about the same degree of fusibility as lead. Crude zinc to make them of may be purchased at a brass foundery. In large towns zinc can be obtained rolled into thin sheets, which only require to be cut to the proper size. In addition to the plates of copper and zinc, it is necessary to be provided with the same number of pieces of woollen cloth, rather smaller than those plates in size. Let these be soaked in a solution of common salt, till they have thoroughly imbibed it: when they are to be used, they must be taken out of the solution and gently squeezed, in order to force out the superabundant water.

The *Voltaic Pile* is to be formed of these materials in the following manner: lay down on a circular piece of wood a plate of zinc, upon that a plate of copper, and then a piece of moistened cloth—let this arrangement be continued—zinc, copper, cloth—zinc, copper, cloth—till all the plates that have been provided are laid on. As the pile began with zinc, it must be concluded with copper. The number of pieces of each substance must be at least twenty, and may be advantageously extended to fifty; for the more pieces there are, the greater will be the effect produced by the pile which they form.

But a pile thus formed, is, when tall, very liable to be overthrown, and must, therefore, in order to avoid this accident, be supported. The method usually adopted to hold it up steadily, is to fix into the piece of wood on which the pile is formed, three rods of glass, which may touch the pieces of metal at three equidistant points. Down these rods may slide a piece of wood similar to the bottom piece, for the purpose of keeping by its pressure the different parts of the pile in close contact. The upper side of the lower piece of wood, and the under side of the upper piece of wood, must be lined with tin-foil.

The zinc plates in the voltaic pile become oxidised, after being used a certain time, and then the galvanic action ceases; but they may be cleaned by being put into diluted muriatic acid, by which the oxide is dissolved. They may also be cleared of the oxide by being filed. It is advisable, when the voltaic apparatus is not to be used for some time, to take it down, by which means the zinc plates will be prevented from wearing out too fast.

EXHIBITION OF THE EFFECTS PRODUCED BY GALVANIC ACTION. —*Process* 1. Place a piece of the metal zinc under the tongue, and a piece of copper (a penny piece) upon the tongue, and bring the extremities of the metals into contact —the result will be the immediate perception of a curious *taste*, something resembling the taste of copperas. The metals have not this taste when not in contact; and, therefore, this experiment clearly shows the influence of excited galvanic electricity upon the organ of taste.

Process 2.—Moisten the under lip; lay upon it a shilling, with the edge of it *beneath* the tongue; lay *upon* the tongue a piece of zinc, and bring the edges of the pieces of metal into contact—instantly, the shilling will feel so intolerably hot, that you will be obliged to let it fall from your mouth. You will then not hesitate to say—galvanic electricity has an influence over the sense of feeling.

Process 3.—Place a piece of zinc under the tongue, and put the small end of a silver tea-spoon in the mouth, between the teeth and the under-lip, passing it up as high as possible, and pressing the extremity of it against the gums; then, let the lower part of the spoon touch the edge of the piece of zinc—at the moment of contact, a flash like lightning appears to the eye, which is renewed as often as you let the two metals touch each other. If you shut your eyes when you perform this experiment, you still see the light; and if you look sternly at a candle or other light, still you see it. Does not this afford ocular demonstration, that galvanic electricity affects the organ of sight?

Process 4.—A Voltaic Pile, constructed as directed above, affords a constant current of the galvanic fluid, for many hours, through any conducting body which may be employed to connect its two ends. If the hands be moistened, and one applied to each end of the pile, or if a rod of metal be held in each hand, and the communication be made by means of them, a shock will be received; the intensity of which is according to the number of pieces that compose the pile; thus, zinc, copper, and cloth, repeated 20 times, forms a pile that gives a shock perceptible to the wrists, and a pile five times as high, gives a tremulous but severe and continued sensation extending to the shoulders.

Process 5.—When a wire communicating with the top of a small pile is held between the teeth, so as to rest upon the tongue (the hands at the same time touching the bottom of the pile), the lips and the tongue will become convulsed, a flash will appear to the eye, and a very pungent taste will be perceived in the mouth.

Process 6.—Put water into a small glass tube (of a diameter of about one-seventh of an inch), and connect the tube, by means of two copper wires, to the Voltaic pile, so that the wire issuing from one end of the tube passes to the top of the pile, and that from the other end of the tube to the bottom of the pile. The wires pass through corks in the ends of the tube, and approach to within a quarter of an inch of one another. The pile, for this experiment, must be formed of at least 50 or 60 sets of plates. After some time, the wire connected with the zinc or positive end of the pile, will be oxidised at the end in the tube; while from the end of the other (the negative) wire in the tube, a stream of small bubbles of gas will arise. This gas is hydrogen; as may be proved by pulling out the cork, and instantly applying an ignited body to the tube, by which the gas will be inflamed. As the gas that is formed in the tube occupies more space than the water that is decomposed, it is necessary to make room in it by allowing some of the water to escape; this is done by cutting a small slit in the cork fastened in the bottom of the tube.—If two wires of gold or platinum (which are not oxidable) be used instead of the copper wires, a stream of gas then issues from each;

and collects at the top of the tube; forming a mixture of hydrogen and oxygen gas, which explodes on the approach of an ignited body.—The gases may be obtained separately, by passing each of the gold wires down a leg of a glass syphon, making them nearly meet at the bottom, and closing the openings at top by means of corks as before. The gas that will be formed will rise up the two legs of the syphon—the hydrogen up the leg containing the negative wire—the oxygen up the leg containing the positive wire —and it will be seen that the gases formed by the decomposition of the water are precisely in the proportions that are required to compose water, namely, two volumes of hydrogen to one of oxygen. In this case, the water that must be suffered to escape to make room in the tube, must pass through a small hole ground in the bended part of the syphon, near where the two wires are opposed to each other.

Process 7.—Fill a glass tube with a solution of acetate of lead, and let the galvanic influence be passed through the tube by copper wires, in the manner described in the preceding process: no gas will be perceived, for the hydrogen arising from the decomposition of the water reduces the oxide of lead held in solution by the acetic acid, and uniting to its oxygen, re-forms water; the lead, in a brilliant metallic state, being precipitated on the negative wire, first in the form of beautiful needles, and then like fern.

Process 8.—Take a glass tube bent into the form of the letter V. Fill it with a solution of sulphate of soda, coloured blue by infusion of cabbage. Put a strip of platinum foil down each leg of the tube, taking care that the two slips do not touch. Connect the extremities with the galvanic pile. In a few minutes the blue colour of the liquor will be changed to *red* at one end of the tube, and to *green* at the other end.

Process 9.—Lay a live flounder upon a wetted plate of copper, and lay on the top of it a piece of zinc; then, by means of a bended wire, make a communication between the pieces of metal placed on each side of the fish; instantly the animal (though previously lying perfectly quiet) will be violently convulsed.

Process 10.—If a piece of zinc and a piece of silver have each one extremity immersed in the same vessel, containing sulphuric or muriatic acid largely diluted with water, the zinc is dissolved and yields hydrogen gas by decomposition of the water; the silver not being acted upon, has no power of decomposing the water; but whenever the zinc and silver are made to touch, or any metallic communication is made between them, hydrogen gas is also formed at the surface of the silver.

Process 11.—Experiments analogous to the former, and equally simple, may also be made with metallic solutions. Take a solution of sulphate of copper; immerse a piece of silver in it, it will come out unchanged; immerse a piece of polished iron—it will receive a coat of copper: bring the iron and silver into contact, and immerse them in the solution together—then, both will be coated with copper.

EXPERIMENTS PRODUCING COMBUSTION, EXPLOSION, AND LIGHT.

Curious Instances of Combustion resulting from Intense Chemical Action.—1. Coarsely powder a few crystals of nitrate of copper, lay them on a piece of tin-foil, add enough of water to make them into a kind of paste, and then quickly fold up the tin-foil, doubling the sides and corners well together, so as to exclude air: in a short time, nitrous gas will force its way out of the packet, and the tin-foil will be set on fire.

2. Fold up a little granulated tin in a bit of thin platinum foil, and hold the packet by a pair of scissars in the flame of a spirit lamp. When a dull red-heat is communicated, combustion is produced, and brilliant minute globules are scattered about in all directions. Combustion is here produced by the combination of the tin with the platinum.

3. See the formation of sulphuret of copper, page 136.

4. When peroxide of lead and sulphur are pounded together in an iron mortar, the mixture inflames and burns with a yellow light.

A Metal which Bursts into Flame when thrown upon Cold Water.—Throw a small piece of potassium upon the surface of water contained in a large dish or flat tray. It will swim, take fire, burn with a delicate violet-coloured flame, finally disappear, and convert the water into a solution of potash.

Flowers of Zinc.—When zinc is melted in a crucible exposed to the open air, it burns with a green flame, and gives out much white smoke, that produces a curious sublimate, page 149.

ANTIMONY VOLCANO.—When antimony is melted in a crucible, and poured from a height of 3 feet on a board raised 2 feet from the ground, it divides into innumerable globules, which fly about in a very surprising manner.

FIRE PRODUCED BY THE MIXTURE OF TWO COLD LIQUIDS.—Into a gallipot, placed upon a hearth stone, under a chimney, or else in the open air, pour about 3 tea-spoonfuls of oil of turpentine; then, mix in a phial about 3 tea-spoonfuls of fuming nitrous acid with $\frac{1}{4}$ part of sulphuric acid, and pour this mixture suddenly upon the oil of turpentine. Instantaneous inflammation, accompanied by the production of a large quantity of black smoke, is the result.—It is advisable to fix the phial, from which the acid is poured, to the end of a long stick, as the sudden expansion occasioned by the combustion sometimes occasions part of the liquid to be thrown out of the vessel.

EXPERIMENTS WITH PHOSPHORUS.—In all experiments with this substance, the greatest degree of care is required, on account of its very combustible nature. A very small portion of it (the quantity is generally mentioned in the experiment) should be operated upon at once. When it is taken in the hands, it never should be held for more than a few seconds, for the heat thus applied is sufficient to inflame it, if continued; and a burn from phosphorus is more painful than any other kind of burn. A basin of cold water ought always to be at hand, to dip the phosphorus in occasionally; and, when it is cut to pieces it must be cut in water. Phosphorus can only be preserved by keeping it in places where neither light nor heat has access. It is obtained from druggists in rolls about the thickness of a quill; these should be put into a phial filled with cold water, that has been previously boiled to expel air from it, and the phial should be inclosed in an opaque case. Experiments made with phosphorus create a very disagreeable smell in the house where the operations are carried on. Young gentlemen should be careful not to annoy their mammas overmuch with this sort of amusement.

WRITING WHICH IS LUMINOUS IN THE DARK.—Trace letters or figures on a smooth board, or on dark coloured paper, with a stick of phosphorus, in the same manner as you would trace them with a crayon. Every line thus made will be beautifully luminous in the dark, and will continue so for some minutes. *Rationale.*—The luminous appearance of the writing arises from a slow combustion of the phosphorus which adheres to the board.

To show the Inflammable nature of Phosphorus.—1. Wrap a grain of it, dried on blotting paper, in a piece of brown paper, and rub it with some hard body; it will set fire to the paper.—2. Put into the middle of some dry cotton, a piece of phosphorus the size of a large pin's head, (previously dried, as before): strike it with a hammer and it will inflame.—3. Upon a piece of glass, lay a small piece of phosphorus, and place the glass upon the surface of hot water in a basin: the phosphorus will inflame.—4. If a chip of dried phosphorus be brought into contact with iodine on a watch glass, inflammation instantly ensues.—5. When oxide of copper is heated with phosphorus in a glass tube over a spirit lamp, a vivid combustion, attended by a green flame, is produced.

Preparation of Phosphorised Ether.—Suffer sulphuric ether to stand, for some weeks, over a quantity of phosphorus in a well-stopped phial. The solution is aided by occasional agitation.

Preparation of Phosphorised Oil.—Put one part of phosphorus with six parts of olive oil into a florence flask, and digest the mixture in a gentle sand heat for two hours. The solution must be kept in a dark place.

To make Waves of Fire on the surface of Water.—On a lump of loaf-sugar, let fall a few drops of phosphorised ether, and place the sugar in a glass of warm water; a very beautiful appearance will be instantly exhibited, and the effect is increased, if the surface of the water is made to undulate, by blowing gently with the breath.

To make the Face and Hands Luminous; so that, in the dark, they appear as if on Fire.—Though the phosphorised oil and ether are luminous in the dark, yet they have not the power to burn any thing; so that either of them may be rubbed on the face and hands without danger; and the appearance thereby produced is most hideously frightful. All the parts of the face that have been rubbed, appear to be covered with a luminous bluish flame, and the mouth and eyes appear as black spots.—When the bottles containing phosphorised oil and ether are opened in the dark, light enough to tell the hour on a watch is evolved.

Brilliant Combustion under Water.—Drop a piece of phosphorus, half the size of a small pea, into a deep glass containing a little cold water. Then add a good quantity of hot water, which will melt the phosphorus, but not inflame it. Then force upon it, from a bladder with a jet-pipe fitted to it, a stream of oxygen gas. Upon this, there will be produced a flame of great vividness below the water.

A Fountain of Fire—formed by phosphuretted Hydrogen Gas.—Put fifteen grains of finely granulated zinc, and six grains of phosphorus, cut in small pieces under water into a conical glass. Mix, in another glass, a drachm by measure of sulphuric acid, with two drachms of water. Now, take the two glasses into a dark room, and there pour the diluted acid over the zinc and phosphorus in the other glass: in a short time, phosphuretted hydrogen gas will be produced, and beautiful jets of bluish flame will dart from all parts of the surface of the liquid, the mixture will be quite luminous, and a quantity of beautiful luminous smoke will rise in a column from the glass. A *Fountain of Fire* is a very apt name for the appearance that is produced. The experiment is very easily performed, and is a very beautiful one.

Curious Property of Phosphuret of Lime.—*Process* 1. Drop a small piece of phosphuret of lime into a wine glass of water: in a short time, bubbles of gas will be produced, which, rising to the surface of the water, will take fire and explode. After each explosion, a beautiful column of white smoke will ascend from the glass. —If the phosphuret of lime be not fresh made, it may be proper to warm the water it is added to. If the residue of the phosphuret of lime be taken out of the water, and, after being dried, have muriatic acid poured upon it, it will inflame.

Process 2.—Put into a glass one part of chlorate of potash, and two parts of phosphuret of lime, in pieces about the size of peas (not in powder), or instead of the phosphuret of lime, use a few small pieces of phosphorus the size of canary seeds. Fill the glass with water, and put into it a tube funnel that will reach to the bottom. Pour through this six or eight parts of strong sulphuric acid, upon which flashes of fire dart from the surface of the fluid, and the bottom of the vessel is illuminated by a beautiful green light.

To make a Powder which Inflames on Exposure to Air. To the substance possessing this property is given the name of *Homberg's pyrophorus:* it is prepared in the following manner. Equal parts of alum and coarse brown sugar are to be mixed together and dried over the fire in an iron ladle, being diligently stirred all the while with an iron rod. The mixture melts, becomes thick, swells up, and runs into small dry lumps. These are coarsely powdered in a mortar, and again roasted till the operator is well assured that the mass contains not the least moisture, when it looks like a blackish powder of charcoal. This must be put, while hot, into a common phial, previously luted on the inside, by being washed with a weak solution of borax, made as thick as cream by the addition of pipe-clay. The phial, when charged, must have a narrow glass tube, six inches long and open at both ends, luted into its neck, and it should be filled three-fourths full only. When ready, it is to be placed in a crucible, or deep iron pan, and covered with sand; and the crucible is to be put into a fire, and heated to redness; a thick smoke will rise from the tube for a quarter of an hour, and be succeeded by a sulphurous vapour, which must be inflamed. When this flame disappears, the operation is completed; the tube must then be closed by a plug of soft clay, and the crucible must be removed from the fire. As soon as the phial becomes cool enough to be handled, the contents of it must be hastily transferred into a dry and warm stout glass phial, which must be secured by a ground glass stopper.—*Experiment.* Throw a little of this powder from the bottle upon some flat dry surface: in a short time it will burst into flame.—*Rationale.* The sulphuret of potash derived from the alum, attracts moisture, or (perhaps) a little potassium formed in the process, attracts oxygen from the air, and generates sufficient heat to kindle the carbonaceous matter mingled with it.

Gay Lussac's Pyrophorus.—This is the most combustible compound of this kind. It forms a shower of sparks when thrown into the air. Prepared by calcining an intimate mixture of 15 parts of lamp-black with $27\frac{1}{3}$ parts of sulphate of potash.

EXHIBITION OF THE POWERFUL DETONATING PROPERTIES OF ALL MIXTURES OF INFLAMMABLE BODIES WITH CHLORATE OF POTASH.—NOTE: In the performance of experiments with chlorate of potash, proceed very cautiously. Never use more than the prescribed quantities. Let the hands be covered with stout gloves, and keep the mixtures, and vessels containing them, as far as possible from the face. Chlorate of potash must never be kept ready mixed with inflammable bodies; for such mixtures sometimes explode spontaneously.

Process 1.—Rub two grains of chlorate of potash, into a fine powder in a mortar, and add one grain of flowers of sulphur. Mix them very accurately, by well triturating them in the gentlest possible manner; and then, having collected the mixture to one part of the mortar, press the pestle down upon it suddenly and forcibly—a loud detonation, accompanied by a flash of light, will instantly ensue.

Process 2.—Let the mixture of the salt and sulphur, just described, be wrapped in some strong paper or tin-foil, and then struck with a hammer—a still louder report will be produced.

Process 3.—Let *half* the quantity of a similar mixture be forcibly triturated in a dry mortar—several explosions, like the cracking of a whip, accompanied by flashes of purple light, take place.

Process 4.—Four grains of the salt are to be reduced to a fine powder, and then mixed with two grains of finely-pulverised charcoal. To this mixture, rather more than one grain of sulphur is to be added; and the whole must be intimately incorporated by mixture, with the least possible friction, on a piece of paper. If this mixture be triturated, it will burst into flame, but not with much noise.

Process 5.—Mix gently but intimately, three grains of the salt, with three grains of loaf-sugar, both previously reduced to fine powder. Place the mixture on a plate, and touch it with a thread or with a glass rod which has just been dipped in strong sulphuric acid—a sudden and vehement inflammation will be immediately produced.

Process 6.—One grain of the powdered salt, with half a grain of phosphorus; wrap the mixture in paper, lay it on a stone or iron, and then strike it with a hammer—a violent detonation takes place instantly.

Process 7.—Put into a glass, one part (about 3 grains) of phosphorus, and two parts (6 grains) of the salt; nearly fill the glass with water; and then convey to the bottom of it, by means of a tube-funnel, three or four parts of sulphuric acid.—A violent action ensues, and the phosphorus burns very vividly, with a curious light, under the water.

Process 8.—Oil may be inflamed on the surface of water, by repeating the preceding experiment, omitting, however, the phosphorus, and substituting a little olive or linseed oil.

Process 9.—If a slip of cotton cloth be dipped in a strong solution of the salt, and afterwards well dried, upon being rubbed in a mortar, it will emit flashes of fire, with explosions similar to the cracking of whips. If the cloth and the mortar be very dry and warm, the trituration causes the cloth to take fire.—Inflammation is also produced by pouring sulphuric acid upon a similar piece of cloth.

Process 10.—If a little of the mixture described at *process* 1, be taken on the point of a knife, and dropped into a wine-glass containing sulphuric acid, a beautiful column of flame will be produced.

Process 11.—Mix a little chlorate of potash with alcohol in a small evaporating dish, and pour a little sulphuric acid over it. It will burst into flame. Do not make this experiment with large portions of the ingredients.

FIRE BOXES.

Prometheans.—When engaged in the performance of chemical experiments, you will often find it very convenient to be able to procure an instantaneous light. You will sometimes want to light a spirit-lamp in order to heat a tube, or a small oil lamp or candle to be used with the blowpipe. In all such cases, it is good to have the power of procuring a light without loss of time.

One of the best contrivances for procuring a light when no fire is at hand, is a little contrivance which has recently become an article of commerce in London, under the name of the *Promethean.* It consists of a roll of paper having a solid red substance enclosed at one end. When you wish to procure a light, you lay the red end of the paper on a table, and give it a knock with a key or other hard body. Thereupon the paper immediately takes fire.

If you soak one of the prometheans in water, and then spread it open, you will find its construction to be extremely simple. The paper is a parallelogram of two inches by one in size, with a triangle cut off at one corner to remove a projection which would otherwise be situate where the red substance is put. This red substance is a mixture of chlorate of potash and sugar, coloured by vermilion, and made into a mass with gum. If you shake it in water, the vermilion precipitates, while the other substances dissolve.

When you come to shake the red substance in water, you find that it is not homogeneous; but that, though itself of no greater bulk than a barley-corn, it contains a vessel of glass of the size and shape of a canary seed, excepting that it is round instead of being flat. This little vessel is closed at both ends, and is easily seen to contain a liquid. If you crush it and put the fragments into water, you will find, by applying a solution of chloride of barium, that the liquid which is contained in it is no other than sulphuric acid.

This is the whole secret of the promethean! When you knock the end of it, you make the imprisoned sulphuric acid come into contact with the mixture of sugar and chlorate of potash; the mixture then inflames, and the inflammation is communicated to the paper.

Directions for making Prometheans.—Take equal parts of finely-pounded chlorate of potash and loaf-sugar; add a small quantity of pulverised vermilion, and mix the whole intimately together; first in the dry state, and afterwards with a solution of gum arabic, by which you make it into a dough.

Caution.—The salts must be well-pounded before they are mixed together, and after being mixed must be treated very gently. A mixture of chlorate of potash with sugar is liable to explode if struck violently, or exposed to very rude handling. You should mix only a small quantity of the compound at once.

To make the glass-beads, hold a thin glass tube over the flame of a lamp, and when the glass is soft, draw it out till it is about as thick as a knitting-needle, or rather until it forms a series of little ovals. Break these asunder so as to leave each oval one-third of an inch long. Close one end by holding it in the flame, then warm the oval by holding it in a pair of pincers over the flame, and while it is hot, dip the open end into sulphuric acid, a portion of which will then rise up into the oval. The open point can finally be closed by being held in the flame, or by having the blowpipe flame directed upon it. The most difficult part of the operation is the closing of the last point, because the heat applied for that purpose is very apt, if clumsily directed, to expel the sulphuric acid from the little vessel.

The paste and the glass beads being provided, you take a slip of paper of the form above described; you spread a solution of gum arabic across that end of the paper where the corner is cut off, and then roll it up into a cylinder, leaving a hollow at the gummed end. You then take a small piece of the red mixture, put one of the glass beads in the middle of it, and force the whole into the open end of the paper roll, in which place you fix it by a gentle squeeze with the fingers. The promethean is then finished, but it requires to be well dried before it can be made to inflame.

PREPARATIONS OF PHOSPHORUS FOR THE INSTANTANEOUS PRODUCTION OF LIGHT.—Put a little phosphorus, dried on blotting paper, into a small phial; heat the phial by placing it in a ladle full of hot sand, and turn it round, so that the melted phosphorus may adhere to its sides. Cork the phial closely, and it is prepared. Another method of preparing it, consists in mixing one part of flowers of sulphur, with eight parts of phosphorus.—On putting a common sulphur match into this fire-bottle, stirring it about a little, and then withdrawing it into the air, it will take fire. Sometimes, however, it is found necessary to rub the match when withdrawn from the phial on a cork, before it will inflame.

INSTANTANEOUS LIGHT-BOXES, sold by Chemists, contain a little bottle, and a number of small matches: you take a match and dip it into the bottle, and quickly withdraw it, upon which it takes fire.—The bottle contains asbestus moistened with concentrated oil of vitriol. It should never be opened except when it is to be used; for the acid, when exposed to the air, imbibes moisture very rapidly, and is soon spoiled. The *matches* are prepared as follows: the ends of some small slips of light wood are dipped into melted sulphur, then into a strong solution of gum, and afterwards into the mixture of chlorate of potash and sugar, prepared as described *page* 311, *process* 5; the powder is fastened to the wood by the gum, and the matches when dry are fit for use.

Lucifers.—Mix equal parts of chlorate of potash and sulphuret of antimony, with gum-water into a paste. Let a little of this paste be applied to each side of one extremity of a thin slip of fir already tipped with brimstone. When the paste is dry, the match may be inflamed by drawing the coated end through a folded slip of sand-paper.

Small pellets of the above paste explode when struck with a hammer. It is the percussion powder used to discharge fowling pieces.

To make Gunpowder.—Pulverise separately 5 drachms of nitrate of potash, 1 of sulphur, and 1 of newly-burnt charcoal. Mix them together, with a little water, in a mortar, so as to make the compound into a dough; which must be rolled out into round pieces, the thickness of a pin, between two boards. Lay a few of these pieces together, and cut them with a knife into small grains which are to be placed on a sheet of paper, in a warm place, to dry. During granulation, the dough must be prevented sticking to the board, by rubbing on it a little of the dry compound powder. The effects produced by the explosion of gunpowder, are so well known, that it would be useless to describe them. It may be observed, however, that the explosion takes place in consequence of the generation of a large quantity of various gases.

Quick Flux.—A mixture of 3 parts of saltpetre, 1 of sulphur, and 1 of sawdust, burns, when set on fire, with such vehemence, that a small piece of silver or copper coin, put in the midst of it, is fused instantaneously. By this means a thin piece of metal may even be *melted in a nut shell* without destroying it.

Fulminating Powder.—Take 3 parts of nitrate of potash, 2 parts of carbonate of potash, and one part of sulphur. Powder them separately, and dry them, by placing them on a tile before the fire. Then, mix them intimately, by rubbing all together in a warm mortar; and preserve the compound in a corked phial.—Let half a drachm of this powder be spread on the bottom of a small iron ladle, and heated over a fire. It gradually blackens, and at last melts, at which instant, it explodes with a violent stunning report: it is not, however, attended by any danger.

Indian White Fire. A mixture of 24 parts of nitre, 7 parts of sulphur, and 2 parts of realgar.

Red Fire for Theatres.—Take

40 parts of dry nitrate of strontian;
13 do. finely powdered sulphur;
10 do. nitre;
4 do. sulphuret of antimony.

The nitrate of strontian and sulphuret of antimony should be powdered separately, and then be mixed with the other articles previously powdered. Sometimes a little realgar is added to the antimony; and frequently, when the fire burns dim, finely powdered charcoal or lamp-black will make it perfect.

Green Fire for Theatres.—Take

13 parts of flour of sulphur;
77 do. nitrate of barytes;
10 do. nitre;
2 do. metallic arsenic;
3 do. charcoal.

The nitrate of barytes should be dried, and powdered alone, and then well mixed with the other ingredients, previously powdered. Calamine may be occasionally used to make it burn slower.

These fires are burnt at the sides and back of the stage, behind standards, &c., to produce strong tints; the red to aid the effect of a conflagration; and the green that of infernal or supernatural appearances—as spectres rising from and sinking beneath the stage, &c. These effects are farther heightened by silk shades of the respective colours before the side and foot lights of the stage. The beautiful effect of moonlight is thus produced.

Port Fire.—The port-fire used for firing artillery is made of three parts of nitre, two of sulphur, and one of gunpowder, well mixed, and rammed in cases; a small quantity of materials will be sufficient to show the appearance which it presents on burning.

Signal Lights.—Signal lights are, in general, composed of nitre and sulphur, with a small quantity of some metallic sulphuret, as that of arsenic or antimony. Mix 600 grains of nitre with 200 of sulphur, and 100 of the yellow sulphuret of arsenic; put the mixture into a cone of paper, and touch it (out of doors or under a chimney) with a red hot iron; it deflagrates rapidly with a brilliant white light.

Mix 100 or 200 grains of the sulphuret of antimony, with the same proportions of nitre and sulphur, and inflame it in the same manner. It deflagrates immediately, with a vivid light, which has a bluish tinge.

Experiments with Fulminating Mercury.—1. Lay about a grain of the powder on a smooth iron, and strike it with a hammer—it will detonate with violence.—2. The third of a grain of it may be enclosed between the ends of two slips of card pasted together, and the other end of the card marked by a notch. If that end of the card which contains the powder be held over a candle, detonation takes place.—3. Half a grain of the powder may be wrapped up with a hard pea in a piece of tissue paper. This, (which is the *fuminating ball*, or *Waterloo cracker*,) when thrown forcibly on the ground, explodes.—4. The other fulminating curiosities, such as *spiders*, &c., are too well known to need describing, and may be easily prepared.—5. Ignite a little fulminating mercury on a piece of plate glass, by applying a small flame below. An explosion will take place, and the glass will become prettily ornamented with reduced mercury, forming a species of mirror when seen from below. Note:—This compound is less dangerous than the fulminating compounds of gold and silver, as it never explodes spontaneously; but yet it cannot be handled with too much caution; and no student should attempt to make it who is not tolerably expert at chemical processes in general.

Fulminating Silver.—When held on a slip of paper over a candle it explodes violently, exerting a downward force, piercing the paper, and extinguishing the flame. Less than a grain of the powder should be used. *It is a dangerous substance to meddle with.*

IODIDE OF NITROGEN.—Rub powdered iodine in a mortar with liquid ammonia; after some time filter the liquid. The filter paper will exhibit a dark brown powder, which is the iodide of nitrogen. 1. It very often explodes spontaneously if dried in too warm a place, so that it requires cautious management. It should be divided, while wet, into small portions, and put on separate pieces of blotting paper to dry. 2. It explodes if gently pressed in a mortar or struck with a hammer, producing a violent report, and a violet light. 3. It explodes in the same way when a bit of paper containing a small portion is lifted with the tongs and thrown on a fire.

Flame is Hollow.—It is a body bright at the surface, and dark within. Its centre is occupied by unburning gases. Stretch a thin platinum wire across the flame of burning alcohol: it will appear red hot only at the surface of the body of flame; or place a straw in the same position, it will be charred only where it cuts the outer edge of the flame.

Intense Heat of Flame.—Set fire to sulphuret of carbon in a capsule, and hold steel wire in the flame. The steel wire will burn beautifully.

COLOURED FLAMES, *which, in the dark, are very curiously reflected by the faces of the spectators.*—To produce coloured flames, certain substances are mixed with burning alcohol.—A beautiful *rose*-coloured flame is produced by inflaming four parts of alcohol, poured over one part of chloride of strontium or nitrate of strontia, in a small iron ladle.—An *orange*-coloured flame is produced, by burning spirits of wine, on chloride of calcium previously deprived by ignition, of its water of crystallisation.—A flame having a fine *green* tinge, is produced by burning alcohol on boracic acid, or nitrate of copper.—A *yellow* flame is produced, by burning alcohol on chloride of sodium.—A bluish-green striped flame is produced by burning a mixture of alcohol and muriatic acid.—NOTE. It should be observed, that the ladle ought previously to be warmed, and ought to be kept heated while the alcohol is burning. The salts remaining behind, after being dried, may be used for the same purpose again. A capsule of porcelain may be employed instead of the iron ladle.

PHOSPHORESCENCE OF FLUOR SPAR.—Sprinkle coarsely powdered fluor spar upon a metal plate or fire shovel, heated strongly, but not to redness, and placed in a dark room. A beautiful phosphorescent light will be exhibited for some time. The same phenomena is produced when a minute piece of fluor spar is held in a dark room at some distance in front of the jet of a small blowpipe flame.

CANTON'S PHOSPHORUS.—Take thick oyster shells, wash them, and keep them red-hot in an open fire for half an hour: then select the whitest parts, and pound them in a Wedgewood's-ware mortar. Mix three parts of this powder with one part of flowers of sulphur, and ram the compound into a crucible, till it is nearly full. The crucible is then to be kept red-hot for at least an hour; and when it has afterwards become cold, the contents of it are to be turned out, and the whitest part scraped off, and preserved in a phial with a ground-glass stopper. If the bottle containing this phosphorus be exposed for a few minutes to the light of the day, and be then taken into the dark, light enough will be emitted to enable one to distinguish the figures on the dial-plate of a watch. If the bottle containing the phosphorus is heated, the luminous appearance increases; if cooled, it decreases. The phosphorescence ceases after a while; but is renewed when the phosphorus is again exposed to light.—*Rationale.* It is generally supposed, that light is capable of entering into bodies, and, after remaining in them, of being extricated unaltered.

BALDWIN'S PHOSPHORUS, WHICH EMITS LIGHT IN THE DARK.—Put some dry nitrate of lime into a crucible, place it in a clear fire, and let it remain in a state of fusion for about ten minutes; then pour it out into a warm iron vessel, and it will become solid; break it into pieces, and enclose them in a well-stopped phial. If this phial be exposed for some hours to the direct rays of the sun, and be then taken into a dark place, the substance within it will emit a considerable quantity of light.

HOMBERG'S PHOSPHORUS possesses the same property as Baldwin's phosphorus, and is prepared in the same manner —only substituting chloride of calcium for nitrate of lime.

LAMP WITHOUT FLAME.—Take platinum wire, about 1-100th of an inch in thickness. Coil it up, and stick the coil loosely on the wick of a spirit lamp. The cotton of the lamp must be very straight, and not pressed by the wire. There should be about 16 spiral turns, one half of which should surround the wick, and the rest rise above it. Having lighted the lamp for an instant, on blowing it out, the wire will become brightly ignited, and will continue to glow as long as any alcohol remains.

A Wire which instantly becomes red-hot when placed in contact with a Vapour.—Let a few drops of ether be thrown into a cold glass, or a few drops of alcohol into a warm one; let a few coils of platinum wire, of the 60th or 70th part of an inch in thickness, be heated to redness by a candle, then, when it has ceased to be red-hot, let it be held in the glass over the ether: in some parts of the glass, it will become glowing, almost white-hot, and will continue so, as long as a sufficient quantity of vapour and air remains in the glass.

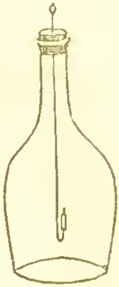
Instantaneous Light produced.—A very small current of hydrogen gas propelled upon a mass of spongy platinum, makes the platinum red-hot, and then takes fire.—*To prepare spongy platinum*:—Evaporate a solution of platinum in aqua regia to dryness, and expose the residue to a strong heat. Dissolve the greenish powder thus obtained in a hot solution of caustic potash, and add alcohol to the mixture. A strong discharge of carbonic acid takes place, and a velvet black heavy powder is precipitated, which consists of finely divided metallic platinum. This powder has the remarkable property, when moistened with alcohol, of becoming red-hot. The spongy platinum must not be squeezed.

AMUSING EXPERIMENTS WITH GASES.

The student should make himself perfectly master of the information relative to the management of gases, given at pages 45—57, and accustom himself to transvase common air with skill before attempting to work with gases. I caution him against putting into operation the experiments of this section, before he has acquired some degree of practical knowledge. Beginners see so many experiments upon gases made during their first visits at the lecture table, and the experiments are generally of so brilliant a description, that they naturally fall into the opinion that they must begin their operations at home with the same subjects. This, however, is a mistake. Experiments with gaseous bodies require much more care and experience, much more apparatus, and a much greater outlay of money, and are attended with more danger and disappointment, than the experiments belonging to many other branches of practical chemistry. I would, therefore, recommend a beginner not to trouble himself with repeating experiments upon the gases, until he has been occupied for some time with experiments on solution, evaporating, crystallisation, neutralisation, precipitation, filtration, &c. He will thus acquire that experience and lightness of hand, which will qualify him to perform more difficult experiments without risk of failure.

OXYGEN GAS.

Oxygen Gas supports Combustion.—Process 1.—Fill a bottle with oxygen gas, and provide a small taper fixed at the end of a wire passed through a cork, as shown in the figure. Light the taper, and plunge it into the gas, taking care to put the light in the middle of the vessel, and not near its sides, otherwise the heat will crack the glass. The flame of the taper will become extremely bright while burning in the oxygen gas.



Process 2.—Fill a small tube with oxygen gas, and hold in it a lighted splinter of wood.

Process 3.—If the light of a taper be blown out, and the taper be let down into a glass of this gas while the snuff, (which should be a thick one) remains red hot, it instantly rekindles, with a slight explosion. When the taper is relighted, it continues to burn, as in the preceding case, with a rapidity, a brilliancy of flame, and an evolution of light truly wonderful.

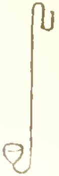
During *combustion in oxygen gas* the volume of the gas often decreases, and, if the combustion continues long enough, the gas wholly disappears. This is owing to a combination which takes place between the oxygen of the oxygen gas, and the body that is burnt in the oxygen gas.

Sometimes the product of such combustion is a gaseous body, and sometimes a solid. Thus, sulphur produces sulphuric acid gas, and carbon, carbonic acid gas;—but, phosphorus produces phosphoric acid, which is deposited in a *solid* state, and a vacuum is produced in the vessel wherein the combination of the two elements takes place.

When combustion takes place in *common air*, the same phenomena occur, but less rapidly, and to a less extent. By burning substances in a given portion of common air, the bulk of that portion of air is diminished one-fifth, and the remaining quantity will support neither combustion, nor animal life. The portion of air thus abstracted has been proved to be oxygen, and the air remaining is nitrogen. And by mixing nitrogen gas and oxygen gas in the abovementioned proportions, a compound is obtained which possesses precisely the same properties as common air. Thus, therefore, the composition, and the proportions of the constituents, of atmospheric air, is proved both by analysis and synthesis.

The grand uses of air being to support life and combustion, and its pure part being abstracted thereby, a continual supply becomes necessary wherever those processes are carried on. This shows us how important it is to renew the fresh air of the rooms we live in, in order that breathing, and the burning of fires and candles, may be readily carried on.

CHARCOAL BURNS BRILLIANTLY IN OXYGEN GAS, AND PRODUCES CARBONIC ACID GAS.—*Process* 1. Fill a bottle with oxygen gas, then put a piece of red-hot charcoal into a *deflagrating spoon*, and plunge it into the gas; allowing the instrument to be sustained in its place, by the cork which is laid upon (not fastened into) the neck of the bottle. The ignited charcoal must not be allowed to go near the sides of the vessel or the glass will crack. As soon as the red-hot charcoal comes into contact with the gas, it begins to burn very vividly, its combustion proceeds with great splendour, and brilliant scintillating sparks are thrown out in all directions. When the combustion is at an end, it will be found that the oxygen gas has been converted into carbonic acid gas. The reason that the cork to which the spoon is attached must not be screwed tightly into the neck of the bottle, is that the gas, upon being heated, expands, and would burst the bottle, were it closely fastened up.

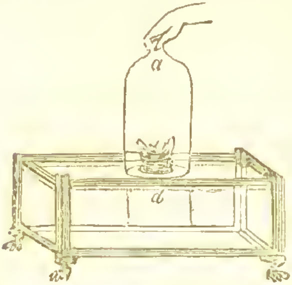


The *deflagrating spoon* is made of copper, the bowl about as big as a shilling, with a long wire handle, which can be provided with a hook at top, to hang it up by when not in use, or be passed through a cork, or soldered to a flat plate of metal, serving to close up the mouth of a jar containing the gas submitted to trial.

Process 2.—The preceding experiment may be performed on a smaller scale, by employing a jar that holds less gas, and using a wire, with a bit of charcoal fastened to the end of it. In this case, beautiful sparks will be thrown out, as before.

SULPHUR BURNS BEAUTIFULLY IN OXYGEN GAS, AND PRODUCES SULPHUROUS ACID.—A piece of sulphur, the size of a pea, is put into the copper spoon, set fire to by a candle and blowpipe, and plunged into the same jar, and in the same manner as directed for performing the experiment with charcoal. The sulphur burns with a beautiful violet-coloured scintillating flame, and the jar becomes filled with sulphurous acid gas. If superfluous oxygen and a little water be present, the latter is converted into very weak oil of vitriol.

SPLENDID COMBUSTION OF PHOSPHORUS IN OXYGEN GAS, AND PRODUCTION OF PHOSPHORIC ACID.—*Process* 1. The light of phosphorus in combustion in oxygen gas, is one of the most splendid that can be produced. Place the size of a small pea of phosphorus in a little hemispherical tin cup, raised by means of a wire stand, an inch or two above the surface of water contained in a broad shallow dish. Fill a large gas receiver, such as *a*, with oxygen gas, and screw on the top of it the bladder *d*, compressed, page 51 ; next open the stop-cocks *b*, *e*, so as to make a communication between the receiver and the bladder ; and then press over the mouth of the receiver, as it stands in the pneumatic trough, a circular piece of pasteboard, rather exceeding its diameter. Bring the receiver filled with oxygen gas immediately over the phosphorus ; let the latter be ignited by an assistant, then remove the pasteboard, and bring down the receiver so as to cover the phosphorus, and immerse it in an atmosphere of oxygen. When this is skilfully managed, a very small portion only of the gas escapes. The inflammation of the phosphorus is so extremely brilliant, that it is almost impossible for the eyes to bear the light. The use of the flaccid bladder is to receive the expanded gas, which is thus prevented from escaping into the room, and proving disagreeable by its suffocating smell—The odorous compound produced is phosphoric acid, which at last settles on the sides of the receiver in white flakes.



Process 2.—When a small quantity of phosphorus and gas is employed, the bladder may be dispensed with, and the experiment performed in the way exhibited by the cut.

Process 3.—The foregoing experiment may be more easily performed, by fastening a bit (of the size of half a pea) of phosphorus to a wire, or putting it in the copper spoon, and then immersing it in a bottle.—The student is particularly cautioned against using larger pieces of phosphorus than those directed.

Iron may be Burned in Oxygen Gas: the Combustion is attended by a Brilliant Light, and the Product is a Metallic Oxide.—Prepare a bottle of oxygen gas and a wire as described below. Light the inflammable matter at the bottom of the wire, and plunge it into the bottle, suspending the whole by the cork. The flame will be instantly communicated to the wire, which will continue to burn with an appearance inconceivably brilliant and striking: proceeding with a meteor-like body, in a spiral form, and throwing out beautiful sparks in all directions.

These sparks, upon being examined when cold, are found to be very different from the iron of which they have been formed.—They are brittle and destitute of metallic lustre. The weight of the drops, too, is greater than that of the metal made use of; so that, in burning, something must have been added to them: this something is oxygen. The term applied to this compound *is oxide of iron*, or iron and oxygen. When the drops fly off in their fused state, they are so hot, that, unless the bottom of the jar be covered an inch or two with sand or water, they are apt to crack it.

The marginal figure represents *a spiral iron wire* with a cork on its upper part that fits the neck of a gas bottle, and on its lower extremity, a bit of tinder. The kind of wire to be used is about 1-30th of an inch thick, and is called by the ironmongers *binding-wire.* In order to bring it into the spiral, or cork-screw shape, it is coiled lightly round a stick of one-third of an inch diameter, and then drawn off. Afterwards, the cork is fitted on, it is drawn out to a proper length, say $\frac{3}{4}$ that of the bottle, and has a morsel of tinder, charcoal, or thread dipped in brimstone or turpentine, fixed upon its lower end.

A steel watch-spring can be burnt in pure oxygen gas, exhibiting a very brilliant appearance.

COMBUSTION OF ZINC, AND FORMATION OF OXIDE OF ZINC.—Substitute, for the phosphorus in the experiment above described, a small ball formed of turnings of zinc, in which about a grain of phosphorus is enclosed. Set fire to the phosphorus, and cover it expeditiously with the jar of oxygen. The zinc will be inflamed, and burn with a beautiful white light.

PROOF THAT METALS ARE INCREASED IN WEIGHT BY COMBINING WITH OXYGEN.—Coil up a drachm of very slender iron wire, put it into the bowl of a pipe and place it in a clear fire. Have ready a bladder filled with oxygen gas. When the iron in the pipe is red hot, force from the bladder, through the pipe, a stream of oxygen gas. The iron will burn very rapidly, and, by combining with the oxygen be converted into oxide of iron. If the bowl of the pipe is kept free from dust, the iron will be found to have increased considerably in weight by its oxidation.

CAOUTCHOUC, CAMPHOR, and many other combustible substances burn in oxygen gas with great energy.

HYDROGEN GAS.

Levity of Hydrogen Gas.—Fill a small jar with hydrogen gas, turn its mouth up and leave it open; in a short time, the gas will have escaped, and the jar be filled with common air. Hydrogen gas can be put out of one vessel into another in the open air, by a species of inverted pouring.

Combustible Nature of Hydrogen Gas.—Apply a light to the mouth of a small jar, or a medicine phial, containing hydrogen gas. The latter will take fire and burn with a pale blue flame, that descends into the glass, and finally disappears.

Hydrogen Gas does not support Combustion.—Into an inverted jar filled with hydrogen gas, introduce a wire bear-

ing a lighted taper on its summit: the flame of the taper will be extinguished.

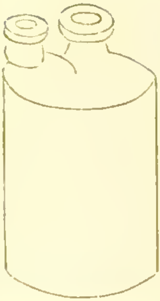
Miniature Balloons.—A mode of Illustrating the extreme lightness of Hydrogen Gas.—Fill a bladder with hydrogen gas, in the manner directed at page 51, and adapt a common tobacco pipe to the mouth of the bladder by means of a stop-cock, or perforated cork. Prepare a strong solution of soap, (a lather such as children use to blow common soap bubbles with,) dip the bowl of the pipe into it, and by compressing the bladder, after having opened the stop-cock, fill soap bubbles with the hydrogen gas. These, when shaken from the pipe, instead of falling downwards, like common bubbles, will rapidly ascend to the ceiling of the room. This experiment affords not only an illustration of the lightness of hydrogen gas, but also of the principles of *Aerostation*: for it is with hydrogen or carburetted hydrogen gas *that air-balloons are inflated.*

If one of these soap bubbles be arrested in its flight by the application of a lighted paper, the hydrogen gas will explode, and the bubble will burst with a vivid flash of light.

Take care not to inflame the bubbles till they are detached from the pipe, or the whole of the gas in the bladder may take fire.

Air-Balloons.—A very pretty apparatus, of recent invention, is now to be had of the philosophical instrument makers. It is a little balloon, in shape resembling a bladder, and is to be had of various sizes. It is made of the maw of a turkey, and is so extremely light, that, when filled with hydrogen gas, and left free in the atmosphere, it *ascends.*—The price of this apparatus is from 1s. 6d. to 6s., according to the size. One of 4 inches diameter will cost about 2s. 6d.

The Philosophical Taper—an illustration of the Combustibility of Hydrogen Gas.—Fit a narrow glass tube into one of the necks of a gas bottle. Then introduce through the other neck, materials for producing hydrogen gas, and close it with a stopper. In a short time, the gas will issue from the top of the tube. Let it escape, till you think as much air has issued as served in the beginning to fill the bottle; then apply to the top of the tube, a lighted paper; upon this the gas will be inflamed, and will burn



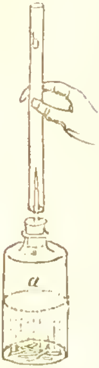
with a bluish-coloured jet, as long as it continues to be produced. This flame is scarcely visible in the daytime, but notwithstanding its dimness, it is intensely hot. The reason that a quantity of air must be suffered to escape has been explained. Hydrogen gas mixed with common air, violently explodes when inflamed, so that particular care is requisite, in this experiment, to let all the common air escape.

Another mode of performing this Experiment, is by fixing a tube to a bladder filled with hydrogen gas,—when, by pressing the bladder more or less, a very pretty jet, or stream of fire, either large or small is easily produced. No danger need be apprehended, because the smallness of the hole in the end of the pipe prevents the flame from entering into the bladder.

ARTIFICIAL FIRE-WORKS are made by passing hydrogen gas through metallic tubes, bent into various forms, and having a number of small orifices bored in them at certain distances. These tubes are affixed to a main pipe which enters the bag or bladder containing the gas; and the gas is forced through them by pressing the bladder. The gas then issues from the small orifices into the atmosphere, and is there inflamed by the application of a lighted candle. If the machine is made partly, or in whole, moveable, a considerable increase is made to the effect. But carburetted hydrogen is much better adapted for this experiment than pure hydrogen.

Meteorologists account for the luminous appearance in the sky, called the AURORA BOREALIS, or *northern lights*, by supposing that a stratum of hydrogen gas, above the atmosphere of common air, is lighted by the electrical fluid, and burns slowly where it comes in contact with common air. The levity of this gas accounts for its ascending to so high a region, and as it can only burn when in contact with the latter, the appearances we observe in the *aurora borealis* are exactly such as we should expect from such a cause.

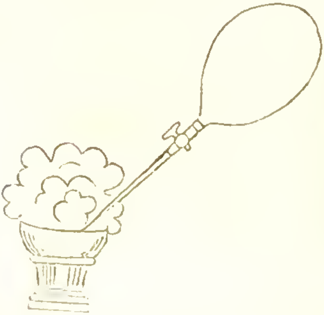
MUSICAL SOUNDS PRODUCED BY THE COMBUSTION OF HYDROGEN GAS.—Take a glass tube, from 18 to 24 inches long,



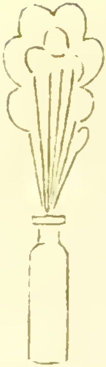
and from 1 to 2 inches wide, and open at both ends. Bring it down a few inches over the flame of the *philosophical taper*, and very strange but pleasing sounds, somewhat resembling those of an Æolian harp, will be immediately produced. By raising or depressing the tube, or by using tubes of different sizes, the intensity of the musical chord may be greatly varied. The production of the sound is occasioned by the rushing of the air into the tube, to supply the vacuum repeatedly formed by the condensation of the oxygen of the air into water, as it combines with the burning hydrogen.

Formation of Water by the Combustion of Hydrogen Gas.—The mode of exhibiting this experiment consists in holding a bell glass over the flame of the *philosophical taper*. The hydrogen gas, as it burns, combines with the oxygen of the atmosphere, and forms water, which is deposited on the internal surface of the glass, in a kind of fine dew.

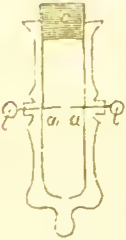
Explosive Powers of a Mixture of two parts of Hydrogen Gas with one part of Oxygen Gas.—Detonating Balloons.—Bubbles blown with this mixture, with the help of a bladder and tobacco-pipe (page 326), will ascend in the air, though not so rapidly as those filled with pure hydrogen. But, upon the application of flame, they will explode with far greater violence; without, however, occasioning any accident, unless they are fired before they are away from the pipe.



If a strong solution of soap, contained in an iron mortar, be blown up by this mixture into a large colliflower head, by means of a bladder and pipe, and a light held at the end of a long stick be applied, an explosion of an extremely violent description is produced, with a report like that of a cannon.

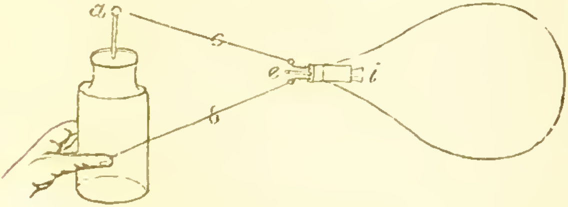


If a similar mixture be put into a strong pint bottle, and the bottle be enveloped in many folds of a coarse cloth, and the mixture be inflamed by withdrawing the cork and applying a light to the mouth of the bottle, a similar stunning explosion is produced.



The electric spark inflames this mixture as readily as common flame. The figure represents a small cannon made of tin plate or brass—*a a*, are two wires with knobs, *b b*, at their outer ends. The wires pass through small glass tubes set in the sides of the cannon, and approach very near to each other without absolutely meeting. Fill the cannon with the mixed gases at the water trough, and close the mouth with a cork. Then pass an electric spark through the mixture from knob to knob. The gases explode, and the cork is thrown out like a shot.

The following is a similar experiment. A A large bladder is closed by a cork, through which passes a glass tube *e* and two wires, the ends of which *nearly* meet inside, and are furnished with knobs outside. The bladder is filled with gas by fixing the tube *e* to the stop-cock of the apparatus depicted at page 51. The tube is closed with wax when the bladder is filled, and the two knobs are connected by wires with the outer and inner side of a Leyden jar. The electric spark passes through the gaseous mixture from wire to wire at *i*, and a tremendous explosion is produced, which shatters the bladder to pieces.



CARBONIC ACID GAS.

TO SHOW THAT CARBONIC ACID GAS EXTINGUISHES FLAME, AND DESTROYS ANIMAL LIFE.—Fill a small confectioner's glass (page 10) with carbonic acid gas, and plunge a lighted candle into it: the flame will be extinguished. A person who is quite a stranger to the properties of this kind of gas, will be agreeably amused by extinguishing lighted candles, or blazing chips of wood, on its surface. As the smoke readily mixes with the gas, and little or none of it escapes into the atmosphere, the smoke floats, in a very curious manner, on the surface of the gas, forming a smooth well-defined plain, which, if the vessel be agitated, is thrown into the form of waves. Insects, which it is desirable to preserve in their true form and brilliancy of colours, for cabinets, may be killed by immersion in carbonic acid gas.

If inflamed sulphur is immersed in a jar of carbonic acid gas, it is extinguished.

PLEASING MODE OF SHOWING THE GREAT WEIGHT OF CARBONIC ACID GAS.—Place a lighted candle in the bottom of a jar which has its open part uppermost, the jar being filled with atmospheric air; take then a jar filled with carbonic acid gas; and invert it over the jar in which the candle is placed: the effect is very striking; the invisible fluid descends like water, and extinguishes the flame. The whole, to spectators who have no idea of substance without sensible matter, having the appearance of *magic!*

A burning candle may be lowered into a basin containing carbonic acid gas, until the top of the wick is about half an inch under the surface of the gas, in which position the flame will remain visible for a few seconds, though *altogether detached from the candle.* The exposition of this phenomena is, that the wick remains hot enough to cause the tallow still to evaporate; and the vapour kindles at the surface of the carbonic acid gas.

It affords an amusing spectacle to let a large soap bubble, filled with common air, fall into a wide glass containing carbonic acid gas. The bubble rebounds from it like a foot-ball, and appears to rest on nothing.

ILLUSTRATION OF THE CHARACTERISTIC POWERS OF OXYGEN GAS, CARBONIC ACID GAS, AND ATMOSPHERICAL AIR, WITH RESPECT TO COMBUSTION.—Set three jars of equal size, mouths upwards, on a table. The first must contain common air; the second, carbonic acid gas; and the third, oxygen gas. Take a lighted candle with a pretty large wick, and lower it, by means of a wire, into the *first* jar—the flame will have its usual brightness. Lower it next into the *second* jar—the flame will be extinguished. Lower it now, while the wick continues red, into the *third* jar—it will be relighted, and will burn for some time with a dazzling splendour. To ordinary spectators, this experiment will be the subject of much wonder. The whole of the jars will, by them, be deemed *empty;* and the different effects resulting from plunging the same candle into seemingly similar vessels, will be quite incomprehensible.

TO SHOW THAT THE ATMOSPHERE CONTAINS CARBONIC ACID.—Expose to the open air, in an open vessel, a quantity of transparent lime water; a white crust will soon form on its surface, which, on being broken, falls to the bottom of the vessel, and is succeeded by another—this precipitate, upon being examined, proves to be carbonate of lime—therefore, carbonic acid is attracted from the atmosphere by the lime in solution.

TO SHOW THAT CARBONIC ACID IS CONTAINED IN AIR RESPIRED FROM THE LUNGS.—*Process* 1. Put into a test glass a little water tinged blue by tincture of cabbage; then, blow into this water, through a tobacco-pipe, air from the lungs—the blue colour will soon be changed to red. This proves that the air blown from the lungs contains *an acid*—now, *query*, what acid is it? Let us see.—*Process* 2. Warm the product of *process* 1, the blue colour will be restored—hence the acid is volatile, and must be either carbonic acid or sulphuretted hydrogen. That it is *not* the latter, may be known by its want of smell; that it *is* the former, may be proved thus;—*Process* 3. Blow air, in the manner described above, into lime or barytic water. The transparent solution will be shortly rendered opaque, by the formation of carbonate of lime, or of barytes.

NITROGEN GAS.

Nitrogen Gas does not support combustion. A lighted taper plunged into it, is extinguished.

TO COMPOSE ATMOSPHERIC AIR.—Mix four parts of nitrogen gas, with one part of oxygen gas. Examine this mixture, by plunging a lighted taper in it, or by any other test you please—it will be found to possess all the properties of common air.

Properties of Nitrous Gas.—1. If an inflamed taper is plunged into nitrous gas, the light is instantly extinguished.

2. Inflamed sulphur is also extinguished, but rekindled when brought again into common air.

3. Inflamed phosphorus burns in it with much splendour.

4. A mixture of equal parts of nitrous gas and hydrogen gas burns quietly with a greenish flame.

5. Homberg's pyrophorus ignites in this gas.

6. When a bottle of it is opened in the air, red fumes of nitrous acid are formed.

7. When three parts of nitrous gas, and two parts of oxygen gas, are thrown up into a glass tube standing over water, the whole disappears, nitrous acid being formed and dissolved by the water.

Properties of Nitrous Oxide Gas.—1. A candle burns in it with a brilliant greenish flame, and a crackling noise. —2. It is heavier than common air.—3. Phosphorus, charcoal, and sulphur burn in it,—as likewise does iron wire.—4. When mixed with oxygen gas, upon the application of flame, it detonates.—5. A chip of potassium thrown up into a jar standing over water inflames and burns intensely. All these things may be proved, by proceeding as directed for performing the experiments which demonstrate the properties of oxygen gas. It must be observed, however, that bodies to be burned in nitrous oxide gas must, when introduced into it, be in a state of complete ignition.

Intoxicating power of Nitrous Oxide Gas.—Though this gas is not fitted to support life, yet it may be respired for a short time, and the effects produced by it upon the animal frame, are its most extraordinary properties. The manner of breathing it is this: put nitrous oxide gas that has been purified by standing over water, into a large bladder, or varnished silk bag, having a wide glass tube, or a stop-cock with a large bore affixed to its neck. Then, hold the bladder by the tube (closing the mouth of the tube by applying the thumb) in the right hand; close the nostrils with the left hand; expel the air contained in the lungs by a long expiration; and instantly apply the tube of the bladder to the mouth, and breathe the gas from and into the bladder as long as possible, which, perhaps, will be about two or three minutes. The effect produced is a sort of delirium, which differs greatly according to the constitutions of the persons by whom the gas is respired. In general, however, the effects are *highly pleasurable*, and resemble those attendant on the agreeable period of intoxication. "Exquisite sensations of pleasure—an irresistible propensity to laughter—a rapid flow of vivid ideas—singular thrilling in the toes, fingers, and ears—a strong incitement to muscular motions"—are the ordinary feelings produced by it. The celebrated Mr Wedgewood, "after breathing the gas some time, threw the bag from him, and kept breathing on laboriously with an open mouth, holding his nose with his fingers, without power to remove them, though aware of the ludicrousness of his situation; he had a violent inclination to jump over the chairs and tables, and seemed so light, that he thought he was going to fly." What is exceedingly remarkable, is, that the intoxication thus produced, instead of being succeeded by the debility subsequent to intoxication by fermented liquors, does, on the contrary, generally render the person who takes it cheerful and high-spirited for the remainder of the day.

CHLORINE GAS.

1. Plunge a lighted taper into a jar of chlorine gas; it burns with a dull red flame, and a copious emission of dense fumes.

2. Add a few drops of water to a quantity of chlorine gas contained in a bottle, and suspend some coloured flowers in the midst of the moistened gas. In a short time, the flowers will be deprived of their colours. This bleaching property is not possessed by dry chlorine gas. In all probability, the effect produced in this experiment is owing to the formation of peroxide of hydrogen.

3. Throw powdered antimony into a long tube filled with chlorine gas, and held mouth upwards. It will produce a shower of burning stars of a yellow light.

4. Powdered metallic arsenic, employed in like manner, produces white stars.

5. Copper leaf introduced into chlorine gas inflames immediately. Dutch gold burns in the same manner.

6. If a slip of paper moistened with spirits of turpentine be immersed in a jar of chlorine gas, it inflames immediately, with evolution of much smoke.

7. Introduce a grain of phosphorus, well dried on bibulous paper, and divided into small pieces, into a bottle of chlorine gas, suspending it in the copper spoon (page 322). It immediately inflames spontaneously, and burns with a pale green flame, producing chloride of phosphorus.

8. Mix one volume of olefiant gas with two volumes of chlorine gas, and inflame the mixture. It burns quickly, with a lurid flame, producing muriatic acid and a deposition of charcoal.

9. A slip of paper moistened with very concentrated liquid ammonia, inflames spontaneously in chlorine gas.

10. Heat a little mercury in a deflagrating spoon, and immediately introduce it into a bottle of chlorine gas. It immediately takes fire, and burns with a reddish flame, producing a chloride of mercury.

11. Camphor, caoutchouc, ether, &c., inflamed and put into chlorine gas, continue to burn therein.

12. Writing done on paper with common ink is effaced when the paper is held in moistened chlorine gas.

13. If equal volumes of chlorine gas and hydrogen gas are mixed and kindled by flame, an explosion is produced. The product is muriatic acid.

14. A solution of chlorine gas in water bleaches vegetable colours.

15. A solution of chlorine gas in water discharges the blue colour of the solution of indigo in oil of vitriol.

16. Many varieties of printed calico are deprived of their colours when held in moistened chlorine gas, or in its solution in water.

17. Melt a little sulphur in the deflagrating spoon, and insert it while liquid into a bottle of chlorine gas. It will immediately take fire, and burn rapidly.

MURIATIC ACID GAS.

1. Fill a long tube with muriatic acid gas. Insert the open end of it into a basin of water coloured blue by litmus. The water will rush up into the tube, absorbing the whole of the gas, and acquiring a red colour from the presence of the dissolved acid.

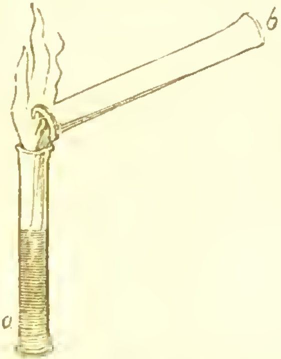
2. Bring a glass containing ammonia gas mouth to mouth with a glass containing muriatic acid gas. White fumes will appear, and settle as a powder on the interior of

the glasses. This is sal ammoniac. If a a little of it is put into a wine glass with lime, it discharges ammonia gas, perceived by the smell. If a little is treated with oil of vitriol, it disengages muriatic acid gas. If any two vessels disengaging ammonia and muriatic acid are brought near to each other, the gases combine, as represented in the cut, and produce a white smoke of muriate of ammonia.

3. An inflamed taper is extinguished by this gas.

4. A bit of ice held in muriatic acid gas very soon melts.

Olefiant Gas.



1. This gas burns with great brilliancy when inflamed at the mouth of a narrow tube, as may be observed in the combustion of the coal gas and oil gas commonly used to illuminate shops, those gases being mixtures of olefiant gas, with some other gases.

2. If an inflamed taper is held to the mouth of a large jar filled with olefiant gas, the gas takes fire, and produces a large and brilliant flame. To expel the gas from the jar, and make it all burn at the mouth, water may be poured in from another vessel; or if the jar which contains the gas is open at both ends, the lower end may be pressed downwards into water.

3. Into a long tube, standing in the water trough, introduce three measures of olefiant gas, and then gradually add four measures of chlorine gas, shaking the mixture after each addition of gas. The tube will become hot, absorption of gas will take place, and white vapours will appear. Finally, upon the disappearance of the gases, an *oil* of a pearl grey colour will be produced, which is heavier than water, has a penetrating and agreeable odour, a sweetish taste, and the property of turning yellow in the air. It is called the hydrocarburet of chlorine.

SULPHURETTED HYDROGEN GAS.

1. A slip of paper having invisible figures drawn upon it with solutions of sugar of lead, nitrate of silver, or nitrate of bismuth, if passed into sulphuretted hydrogen gas, unfolds its secrets, by exhibiting legible figures of a beautiful dark brown colour.

2. Moistened blue litmus paper becomes red in this gas.

3. Paper dipped in nitric acid becomes yellow in sulphuretted hydrogen gas, acquiring a coating of powdered sulphur.

4. A mixture of equal measures of oxygen gas and sulphuretted hydrogen gas produces a smart detonation when inflamed in the same manner as a mixture of oxygen and hydrogen gas (page 329).

5. Sulphuretted hydrogen burns in contact with the air, with a pale blue flame.

6. Sulphuretted hydrogen gas is readily absorbed by alcaline solutions, which produce solutions of metallic sulphurets.

SULPHUROUS ACID GAS.

1. If a lighted candle is let down into a jar of this gas, it is immediately extinguished. When the gas is breathed, even when largely diluted with common air, it excites violent coughing.

2. Sulphurous acid gas bleaches a great variety of vegetable colours, sometimes first turning them red. Its solution in water produces the same effect.

3. This gas is rapidly absorbed by water. If a bottle of cold water, saturated with this gas, is plunged into a basin of hot water and uncorked, an infinite number of small bubbles will be instantaneously extricated, and the water in the bottle will appear to boil.

AMMONIA GAS.

1. If a lighted taper is plunged into a jar of this gas, the flame is first very much enlarged and then extinguished.

2. It is so much lighter than common air, that if a jar filled with it be left open with the mouth upwards, the gas is soon exchanged for common air.

3. Moistened turmeric paper is turned brown when held in ammonia gas. Paper tinged with blue cabbage liquor turns blue in the same situation.

4. If carbonic acid gas and ammonia gas are mixed together, they condense into a solid white compound.

FLUOBORIC ACID GAS.

White paper plunged into this gas is instantly turned coal black: the reason is, that the paper is decomposed, and new compounds formed by the oxygen and hydrogen of the paper and the elements of the fluoboric acid. The charcoal of the paper is thus set at liberty.

IODINE.

Combustion of Potassium in Iodine.—Take a tube like *c*, (page 12). Put a little iodine at the bottom, and a bit of potassium in the middle of the tube, on the horizontal part. Volatilise the iodine by heat, and when the tube is full of its beautiful vapour heat the potassium by holding a lamp below it. The metal will then burn with a violet light in an atmosphere of iodine.

Production of a Gas possessing a splendid Violet colour.—Iodine is prepared with some difficulty, and is expensive. But, at the shops where chemical preparations are sold, small glass tubes, hermetically sealed, and containing two or three grains of it, may be purchased.—If one of these glass tubes is gently heated, by holding it over a lamp, the iodine is converted into a beautiful violet-coloured vapour.

ILLUSTRATIONS OF CHEMICAL ARTS.

INK-MAKING.

PREPARATION OF WRITING INK.—*Process* 1. Take two ounces of gall-nuts in coarse powder, one ounce of logwood in thin chips, one ounce of sulphate of iron (green vitriol), three-fourths of an ounce of gum-arabic in powder, one-fourth of an ounce of sulphate of copper (blue vitriol), and one-fourth of an ounce of sugar-candy. Boil the galls and logwood together in three pints of water, till the quantity is reduced to one-half; when the liquor must be strained through a flannel into a proper vessel, and the remainder of the ingredients be added to it. The mixture is now to be frequently stirred, till the whole is dissolved: after which, it must be left at rest for 24 hours. The ink may then be decanted from the gross sediment, and must be preserved in a glass or stone bottle, well corked.—Writing performed with this ink has a beautiful black cast, which it retains, unaltered, for a considerable length of time.—There is an inconvenience attending the use of the sulphate of copper, (which some, therefore, dispense with,) that requires notice:—upon mending a pen, which is moist with the ink, a film of copper is deposited upon the edge of the penknife, and takes considerably from its keenness. NOTE: —Ink-holders ought always to be made of *glass*.

Process 2.—Take four ounces of the best galls; two ounces and a half of sulphate of iron calcined to whiteness; two pints of water: and ten drachms of gum-arabic. The galls and calcined vitriol are to be left to macerate for 24 hours, then the gum is to be added, and the mixture is to be preserved in a stone jar, open, or merely covered with paper.

INK POWDER.—For the use of travellers, who may not find it convenient to carry liquid ink with them, the materials used for producing good ink may be finely powdered, and intimately blended together; by which means, an ink powder is made, from which, at any time, good ink may be extemporaneously prepared, by mere mixture with water.

COLOURED INKS.—*Red.* Boil an ounce of Brazil-wood, in fine chips, in half a pint of water, for a quarter of an hour: and add to the decoction, three drachms of gum-arabic, and as much alum as it will dissolve.—*Fine Red Ink.* Boil four ounces of raspings of the best Brazil wood, and one ounce each of crystals of tartar and powdered alum, in a quart of the clearest river water, till half the fluid is evaporated. While it is yet warm, dissolve in it an ounce each of double refined sugar and white gum-arabic. This will produce an ink of a lively red hue, and very permanent.—*Blue.* Diffuse Prussian blue or indigo through strong gum-water.—*Yellow.* Dissolve gamboge in gum water.—*Scarlet.* Dissolve vermilion in gum-water.—Inks of other colours may be made from a strong decoction of the materials used in dyeing, mixed with a little alum and gum-arabic.

PERMANENT INK FOR MARKING LINEN.—Dissolve a drachm of lunar caustic (fused nitrate of silver) in thrice its weight of water, and add about half a drachm of gum-arabic. This forms the *ink*, with which you must write, or rather *paint*, with a clean pen, upon the linen prepared as follows: dissolve half an ounce of sub-carbonate of soda in an ounce of distilled water, and add 20 grains of gum-arabic; this forms the *mordant*. Well moisten, with the mordant, the part of the linen that is to be written on, dry it well by a gentle heat, rub the surface of the linen smooth with a round piece of glass or china, and then apply the ink in the manner above directed, to the place that has been moistened. The writing, when exposed to the sun, becomes black.

INK FOR PRINTING ON LINEN WITH TYPES.—Dissolve one part of asphaltum in four parts of oil of turpentine, and add lamp-black or black-lead, in fine powder, in sufficient quantity to render the ink of a proper consistence for printing with types.

Small German Printing Presses, furnished with *Types*, &c., adapted for this purpose, may be had of most stationers and toymen, at various prices, from 3*s*. to 15*s*.

INDELIBLE INKS, USEFUL FOR WRITING LABELS FOR BOTTLES CONTAINING ACIDS, &c.—1. Take oil of lavender, 200 grains; gum copal, in powder, 25 grains; and lamp black, 3 grains. Dissolve the copal in the oil of lavender, in a small flask or phial, by the aid of a gentle heat; and then mix the lamp black with the solution, by trituration in the Wedgewood's-ware mortar. After a repose of some hours, the ink, before use, requires to be shaken, or must be stirred with an iron wire. If it be found too thick, it may be diluted with a little oil of lavender, or of turpentine.—2. A solution may be made, in like manner, of 120 grains of oil of lavender; 17 grains of copal, and 60 grains of vermilion.—3. Boil one ounce of finely-rasped Brazil-wood, and half an ounce of alum, in 12 ounces of water, till the liquid is reduced to 8 ounces; then decant the clear part, and add to it an ounce of calcined manganese mixed with half an ounce of gum-arabic.

COLOUR-MAKING.

SCHEELE'S MINERAL GREEN.—Boil a bit of white arsenic in a solution of potash in a glass tube. This produces a solution of arseniate of potash, which, on being poured into a solution of sulphate of copper, produces a green precipitate of arseniate of copper. Filter, wash, and dry the precipitate. It is Scheele's mineral green.

MINERAL GREEN.—This colour is prepared by adding a solution of carbonate of potash to a hot solution of sulphate of copper (blue vitriol). A green precipitate is produced, which is basic carbonate of copper. You let it settle, pour off the liquor, and wash the residue.

MINERAL YELLOW.—Obtained by igniting a mixture of one part of sal ammoniac with four parts of red-lead. It produces a fused, heavy, yellow crystalline mass. It is a compound of lead, chlorine, and oxygen.

LAKE.—Boil chips of fine Brazil-wood in water. Strain the decoction, and add to it a solution of tin in muriatic acid, which may be purchased of the drysalters as *tin-salt*. The mixture affords a fine red precipitate, which is the lake required.

Another sort of lake is obtained by precipitation with solution of alum instead of tin-salt.

Various coloured lakes may be obtained by digesting fine Brazil-wood in acids, filtering the solution, and precipitating with alum and ammonia, or alum and potash; but ammonia gives the finest-coloured lakes. The precipitate is extremely bulky at first, but contracts very much during the operation of drying.

CARMINE.—Take three pints of water that has been boiled in a pewter kettle. Add to it an ounce of finely-pulverised cochineal, and boil it again for ten minutes. Then add half a drachm of cream of tartar, and the same quantity of Roman alum, and keep the whole on the fire for a minute or two longer. When the gross powder has subsided, the decoction is to be decanted into tall cylindrical glasses, which are to be covered over, and left undisturbed. The carmine then settles in a fine powder at the bottom of the glasses. The liquor is to be gently poured off, and the powder gradually dried.

An inferior carmine is obtained by adding a solution of chloride of tin to the coloured liquor poured off from the precipitated carmine in the above experiment.

LIGHT RED, or *Burnt Ochre*, is common yellow ochre made red-hot in the fire.

TERRA DI SIENNA.—Dissolve iron in a diluted acid, and precipitate it by a solution of an alcali.

BLACK CHALKS FOR DRAWING.—Saw fine-grained charcoal into the size of crayons. Put them into a pipkin containing melted bee's wax, and allow them to remain near a slow fire for half an hour or more, according to the thickness of the crayons. If the crayons are required to be hard, you must mix a little rosin with the wax. If you want them soft, you must add butter instead of rosin.

CHROME YELLOW.—Prepare a solution of sugar of lead and a solution of chromate of potash. If you mix these together, a fine yellow precipitate is produced. This is chromate of lead, or pure chrome yellow. The chrome yellow of commerce contains sulphate of lead, pipe clay, and various other impurities.

CAKE WATER COLOURS.—Prepared of extracts of the usual dyeing substances, made up with gum-water and a little isinglass jelly, and squeezed into greased moulds.

CRAYONS.—Take three ounces of spermaceti, one pound of finely-powdered bone ashes, one pint of water, and mix into a mass; add the proper proportion of colouring matter, namely, ochre for red crayons, chrome yellow for yellow crayons, &c. Roll out the paste, and when half dry cut it into pipes.

DYEING.

TO DYE BROWN ON WOOL.—Boil green walnut shells in water, strain the decoction, make it hot, and let a skein of wool soak in it till sufficiently dyed. Afterwards, wash the wool several times, to take off all the dye that is not incorporated with the stuff.

ROSE COLOUR ON SILK.—Wash carthamus or safflower till it ceases to colour water yellow. Mix 2 drachms of this washed and dried carthamus with 18 grains of potash and 7 drachms of spirits of wine. Let the mixture macerate in the cold for two hours; then add two ounces of cold water, and let it macerate two hours more. After which, strain it through a cloth, and add lemon juice to it, until it becomes of a cherry colour. This bath is used to dye silk.

SAXONY BLUE ON WOOL.—Into a quantity of hot water, pour a little of the solution of indigo in sulphuric acid (page 124). Put a skein of wool into the hot blue liquor, and let it soak till dyed sufficiently.

YELLOW ON SILK.—Three drachms of yellow wood, cut into small pieces, are boiled in eight ounces of water, and the decoction is strained. Into this, while very hot, a skein of *alumed* silk is plunged, and allowed to remain till sufficiently coloured.

To alum Silk, is to soak it in a solution of alum in water.

The alumed silk must be well washed before it is dipped into the colouring bath, otherwise the superabundant alum will precipitate all the colour of the dyeing liquor in clots. The washing of the alumed silk does not take away that portion of alum which has properly combined with the silk.

FINE CRIMSON ON SILK.—A decoction is made of a drachm of cochineal in four ounces of water, and six drops of solution of chloride of tin are added. Into this a skein of alumed silk is dipped, which, in a short time, is dyed a fine crimson.

SCARLET ON WOOL.—Half a drachm of cochineal is boiled in eight ounces of water, and to this is added a drachm of solution of chloride of tin previously mixed with the same quantity of water. A piece of woollen stuff is plunged into this bath, and boiled till it is sufficiently coloured. Thread, cotton, and silk do not take this dye.

FRENCH WHITE ON SILK.—Boil a quarter of an ounce of white soap in a gallon of water, and add a tea-spoonful of red archil. Put the article you wish to dye into the bath, and let it boil for about 20 minutes. Add more archil, if the shade is not sufficiently blue. Remove the article from the bath into a towel. Wrap it up, and wring it very hard to get out the dye liquor. Hang it up to dry in the shade.

For PEACH BLOSSOM, use twice as much soap, and four times as much red archil, to the above quantity of water.

PEARL WHITE ON SILK.—The same process as the preceding. You require, however, to use blue archil, and to add pearl ashes.

PINK ON COTTON.—A quantity of safflower is to be put into a woollen bag, and washed and squeezed in water, until it ceases to give out yellow colour, which is to be thrown away. Take of the washed safflower 1 pound, mix it with 1½ ounce of pearl ashes, put it in a tub with water, let it soak for 8 hours, and then strain off the clear liquor. Mix the safflower with 1 ounce more pearl ashes, and let it soak in a fresh quantity of water for 4 hours. Then strain and mix the two liquors.

Take a pound of cotton, and turn it in the alcaline liquor. Pour in as much oil of vitriol as just neutralises the alcali (see page 23). Turn the cotton for half an hour, then add a little more oil of vitriol to make the liquor sour; and again turn the cotton for two hours, by which time it will have abstracted the colouring matter from the bath. Remove the cotton, and wash it first in clean spring water, and then in water containing an ounce of cream of tartar. It may be left to soak in the latter for a quarter of an hour. Wring it out, and dry it in the shade.

Pink on Silk.—Prepare a bath of safflower, as directed under "Rose colour on Silk," or else by soaking cotton dyed pink in a solution of carbonate of soda. Add lemon juice or tartaric acid to the liquor to precipitate the colour, but do not make it too sour. Wash the silk in the bath for 20 minutes, then add more lemon juice, and turn the silk for a quarter of an hour longer. If you make the bath too sour, the colour will be dulled.

If you want to produce *light pink*, you should previously dye the silk French white. If you require a *rose colour*, you should begin by dyeing it peach blossom. But the intensity of the final colour depends upon the strength of the last colouring bath. The silk is to be cleared by washing in spring water containing a very little tartaric acid.

Pink White on Silk.—This is readily produced by first dyeing the silk a French white, and then giving it a feeble shade of pink by the process last explained.

Sky and Saxony Blue.—Wash the silk in water containing a little alum, and then soak it in water containing indigo dissolved in oil of vitriol (page 124). The depth of the tint depends upon the quantity of sulphate of indigo you add; wash the silk in water containing alum.

Waterloo Blue on Silk or Cotton.—First dye the articles buff in a liquor prepared by mixing water with a small quantity of solution of perchloride of iron (page 148), or of iron dissolved in nitric acid, or in vinegar, say half an ounce of iron liquor to each pint of water. The depth of the blue finally produced depends upon that of the buff you first produce, and which you regulate by the quantity of the iron liquor. Turn the articles in the dye bath for about twenty minutes.

Dissolve prussiate of potash in lukewarm water in another vessel, and make the liquor rather sour by adding oil of vitriol. Keep the liquor warm, turn the silk or cotton in it for about a quarter of an hour, and then remove and wash it. An ounce of prussiate of potash is enough to dye a silk dress by this process.

YELLOW ON SILK.—*Various shades, from a Canary colour to a deep yellow.*—First soak your silk in alum water, using more or less alum according to the depth of the tint you wish to produce. Afterwards wash your silk. Then prepare a dye-bath, by boiling *weld* in water, till the stalks are tender, and strain the liquor. Take a fourth part of it, and reduce to a lukewarm temperature by adding cold water. Soak your silks in this liquor for a quarter of an hour, then wring them out, and put them into the other weld liquor, kept considerably hotter. When the proper shade is produced, wash the silks in a soap lye, containing 1 ounce of soft soap and half a gallon of water to half a pound of silk. The light shades of yellow are produced by weak solutions, both of the alum mordant, and the weld dye-bath.

PRIMROSE ON SILK.—The silk must be alumed very slightly, and then turned for a quarter of an hour in a warm weld dye-bath, mixed with a few drops of sulphate of indigo to give it a greenish tinge, which you can make as decided as you please. Afterwards wash and dry the silk in the air.

AMBER OR GOLD COLOUR ON SILK.—Boil a small quantity of Spanish annatto, with about a quarter as much pearl ashes in a quantity of water, and turn your silk in the strained decoction, until it acquires a lightish orange colour. Then wash it, pass it through alum liquor, and wash it again. After which, dye it in a strong bath of weld, wash it in a solution of soft soap, and dry it before the fire. The stronger you make the annatto ground, the redder is the colour ultimately produced.

ORANGE ON SILK.—Take 3 ounces of Spanish annatto, and soften it by squeezing and soaking in warm water. Add 1 ounce of white soap and 1 ounce of pearl ashes. Boil the whole for ten minutes in rain water, in a clean copper kettle. Pour off the clean liquor through a cloth to strain it, put in the silk, let it remain for an hour, remove it, wash it, and dry it before the fire. Preserve the residual liquor for grounding other colours.

LEGHORN ON SILK RIBBONS OR TRIMMINGS.—Add to a gallon of water, about a gill each of decoction of annatto and of fustic, observing that the annatto produces a reddish, and the fustic a yellow tinge. Stir the mixture well, and then turn the articles in it till they receive the proper colour.

BRIGHT BUT FUGITIVE YELLOW ON SILK.—Macerate turmeric in spirits of wine or whisky. Filter the tincture, dilute it with whisky, and soak the silk in it. Afterwards wash it in water, and dry it before the fire.

CHEAP YELLOW ON SILK FROM QUERCITRON BARK.—First soak the silk in alum water and wash it well. Boil quercitron bark in water, using bark equal in weight to one-third of the silk. Tye up the bark in a thin bag, and squeeze it frequently while in the water. If a very bright colour is wanted, add a small quantity of solution of tin. Remove the bark, allow the liquor to cool till the hand can bear the heat, insert the silk, turn it frequently, and keep the water in agitation to prevent the colouring matter from subsiding. When the silk has gained the proper shade, remove it from the bath, wash it thoroughly, and dry it before the fire or in the air.

PURPLE ON SILK.—Cudbear boiled in water, and altered to blue by pearl ashes, or to red by lemon juice, produces a great variety of beautiful shades of purple.

BLUES AND GREYS ON SILK.—Use a decoction of logwood mixed with solution of chloride of tin and sulphate of indigo.

RICH BROWN ON SILK.—Soak the silk in alum water, wash it, and then dye it in a decoction of peach wood and fustic.

FRENCH BLACK ON SILK.—Mordant with iron liquor. See "Waterloo Blue." Then dye in a bath of decoction of logwood and pearl ashes.

GREEN ON SILK.—First dye it yellow with decoction of fustic or tincture of turmeric, and then pass it through a bath of very dilute sulphate of indigo.

OLIVE GREEN ON SILK.—Alum the silk, dyc it in a mixed decoction of fustic and logwood, and subsequently in sulphate of indigo; the dye-baths being kept warm.

CALICO PRINTING.

TO PRODUCE A WHITE PATTERN ON A BLACK GROUND.—Let a piece of white calico be dipped in a cold solution of sulphate of iron, and dried. Then imprint any figures upon it with a strong solution of colourless citric acid, and let this dry also. If the piece be then well washed in warm water, and afterwards boiled in a decoction of logwood, the ground will be dyed either a slate or black colour, according to the strength of the metallic solution, while the printed figures will remain beautifully white.

To produce a Scarlet pattern on a Black ground.—Dip a piece of white calico in a strong solution of acetate of iron (which may be made by boiling sulphate of iron with acetate of lead); dry it by the fire and lay it aside for 3 or 4 days. After this, wash it well in hot water, and then dye it black by boiling it for ten minutes in a strong decoction of logwood; and, lastly, rinse it in water, and let it dry. Now, any figures printed upon it with a *colourless* solution of tin, will acquire a beautiful scarlet colour—though the ground remains black.

Of Dyeing different colours with the same Liquor.—Add to the solution of sulphate of indigo an equal quantity of solution of carbonate of potash.—If a piece of *white* cloth be dipped in this mixture, it will be changed to *blue;* in the same way, *yellow* may be changed to *green;* and *red* to *purple;* and a piece of *blue* litmus paper will become *red.*

Yellow figures on a Red ground.—Calico dyed red with madder is bleached according to a certain pattern, by the topical application of a solution of bleaching powder. If the white spots are painted with a solution of sugar of lead, and the cloth is afterwards dipped in a solution of bichromate of potash, the result is a red cloth with yellow figures upon it.

Direct application of Colours to Calico.—Many colours are applied without a mordant, the coloured liquors being stiffened with starch and printed on the cloth by means of blocks cut to certain patterns.

Bleaching.

Illustration of the Art of Bleaching.—Put into a phial of liquid chlorine, strips of linen cloth, dyed of different colours—the colours will be quickly discharged.

Bleaching power of Chloride of Lime.—Make a clear solution of chloride of lime, or bleaching powder, and immerse a strip of pink-coloured paper in it. The paper will come out white.

Linen cloth stained by fruit or wine, is purified from the stains by the same solution.

Extemporaneous Formation of a Bleaching Liquid.—Add a few grains of chlorate of potash to a spoonful of muriatic or sulphuric acid diluted with half a wine-glassful of water. The liquid thus formed will possess the bleaching property of that described in the preceding paragraph.

To remove Ink stains from Linen.—Rub the stains with a solution of oxalate of potash.

To remove Ink Stains from Books, Linen, &c.—Apply to the spot, muriatic acid diluted with five or six times its weight of water, and, after a minute or two, wash it off: repeating the application as often as may be found necessary. Strong solutions of oxalic, citric, and tartaric acids, also effect the purpose, and being less likely than the muriatic acid to injure the fabric they are applied to, are preferable.

To clean White Leather, Boot Tops, Book Covers, &c.—Dissolve a drachm of chlorate of potash, in 2 ounces of water, add 2 ounces of muriatic acid, and then a mixture of 3 ounces of rectified spirit of wine with half an ounce of essential salt of lemons, previously well shaken together. Keep the mixture corked up for use. It is applied by means of a sponge and dried at a gentle heat. The leather is afterwards polished by a brush.

Bleaching Liquor for Family Use.—Take of Tennant's Bleaching Powder, one ounce; of water, one imperial gallon. Dissolve the bleaching powder in a tea cup in a little of the water, stirring it with a bit of stick or a bone egg-spoon. When the mixture is of a uniform consistence, and no dry powder floats upon the surface of the liquor, pour it into the remainder of the water, and stir the whole for a few minutes to make it mix well. Then let it settle for an hour, during which time a sediment will fall to the bottom, and afterwards decant the clear liquor for use. If you wish to keep the bleaching liquor in a prepared state, you may allow an ounce of powder to a quart bottle of water. To this liquor you must add as much water as will make up a gallon at the time when you find it convenient to use it.

How to use the above Bleaching Liquor.—The linen or cotton which you wish to bleach, being first well washed, is to be steeped in the bleaching liquor from one to three hours. The cotton must be kept under the surface of the liquor, so that no part of it be exposed to the air. It is then to be taken out and immediately well rinsed in cold water. The time of the steeping must be regulated by the colour of the things to be bleached; if they are dark-coloured, it must be long; if light-coloured, short. But, as I have said, it is to be always between one and three hours.

Cautions.—You cannot bleach silks in this manner, but only linens and cottons. The things to be bleached must be rinced after steeping and before being dried, otherwise they may be burned, or so injured as to become rotten. If you take care to rinse the articles as soon as you take them out of the bleaching liquor, there is no fear of the occurrence of this accident. You must put the bleaching liquor into a vessel of wood, glass, or earthern-ware, and not into a metallic vessel.

METALLIC ARTS.

Aurum Musivum.—This substance, which is employed to give a beautiful appearance resembling a sprinkling of powdered gold to snuff-boxes, coaches, &c., is prepared as follows:—Take of tin two parts, of mercury one part, of sulphur one and a half parts, of sal ammoniac one part. Melt the tin, add to it the mercury, triturate the amalgam with the other ingredients. Put the mixture into a glass matrass, plunge the latter rather deep into sand, and keep it in a gentle heat for several hours, or until the mixture ceases to exhale white fumes. Then raise the heat and sustain it for several hours longer.

MOIREE METAL, OR CRYSTALLISED TIN.—Clean a piece of tin from dirt or grease, by well washing it with warm soapy water; and rinse it in clean water. Then, heat the tin to the temperature of bare sufferance to the hand, and pour on it, or apply with a brush or sponge, one of the following mixtures.—1. Dissolve two ounces of chloride of sodium in four ounces of water, and add one ounce of nitric acid.—2. To two ounces of water, add half an ounce of muriatic acid, and one-fourth of an ounce of sulphuric acid.—3. Either of the preceding in a greater or less degree of dilution.—When the mixture has been applied, the tin is to be dipped into water slightly acidulated, and afterwards well washed in clean water. This process will cause the tin to assume an appearance of great beauty: an apparent crystallisation takes place, somewhat resembling mother of pearl; and curious figures, stars, and rude leaves appear. A transparent varnish (either coloured or colourless) may be laid on now, which will give a fine polish to the work, and produce that brilliant covering so much employed for snuffer stands, for covering pillars in shop-windows, &c.

GOLD VARNISH to be laid on the tin which has been ornamented by undergoing the process just described.—Take of shell-lac two ounces of annatto and turmeric, of each one ounce, of dragon's blood thirty grains: make an extract with twenty ounces of alcohol in a gentle heat.

TO SILVER COPPER.—Precipitate silver from a solution of nitrate of silver, by the immersion of polished plates of copper. Take of this silver 20 grains, of super-tartrate of potash 2 drachms, of common salt 2 drachms, and of alum half a drachm; mix the whole well together. Take then the article to be silvered, clean it well, and rub some of the mixture, previously a little moistened, upon its surface; the silvered surface may be polished with a piece of soft leather. —The dial-plates of clocks, scales of barometers, &c., are all plated thus.

TO MAKE BRASS.—Put into the bowl of a large tobacco-pipe a portion of copper filings, mixed with about twice its quantity of finely granulated zinc; cover it with charcoal powder, and press it well together; then, expose it to the action of a clear fire for some time:—the two metals will combine and form brass.

TO MAKE PEWTER.—Melt, in a crucible, one part of lead, or bismuth, with about twenty parts of tin.

TO DISTINGUISH IRON FROM STEEL.—Let a drop of diluted nitric acid fall on the metal; and after a few minutes wash it off with water. If the metal be steel, a black spot will be left on it; if it be iron, a whitish-grey spot will remain. —*Rationale.* The nitric acid dissolves the iron in both cases; but the charcoal that enters into the composition of the steel, remains undissolved, and constitutes the blackness.

EASY METHOD OF MAKING BEAUTIFUL GOLDEN FIGURES UPON STEEL.—Add to a saturated solution of chloride of gold, about a fourth part of sulphuric ether; shake the mixture, and then allow it to settle. The ether will take the gold from the chloride, and will separate in combination with the gold from the water of the solution, and form an upper stratum in the vessel. Carefully pour this etherial gold into another glass, and immerse in it any steel utensil that is highly polished, then take it out and instantly plunge it into water—when the surface will have acquired a coat of pure gold, the beauty of which may be increased by burnishing.—You may use a pen, and draw figures on razors, &c., and the gold will remain on them as just described.

AN ALLOY WHICH MAY BE KEPT IN FUSION UPON A PAPER HELD OVER A CANDLE.—Melt together in a crucible—lead one part, zinc one part, and bismuth one part.

SPOONS WHICH MELT IN HOT WATER.—Fuse together in a crucible, eight parts of bismuth, five of lead, and three of tin: these metals will combine, and form an alloy, of which spoons may be made, possessed of the remarkable property of melting in boiling water.

DOMESTIC ECONOMY, PERFUMERY, &C.

PREPARATION OF GINGER-BEER POWDERS.—Take 2 drachms of fine loaf sugar, 8 grains of ginger, and 26 grains of bicarbonate of potash, all in fine powder—mix them intimately in a Wedgewood's-ware mortar. Take also 30 grains of citric or tartaric acid, (the first is the pleasantest, but the last the cheapest.) The acid is to be kept separate from the mixture. The *beer* is prepared from the powders thus: take two tumbler glasses, each half filled with water—stir up the compound powder in one of them, and the acid powder in the other: then mix the two liquors—an effervescence takes place—the beer is prepared, and may be drunk off. The effervescence is occasioned by the discharge of the carbonic acid of the carbonate of potash. If the beer is allowed to stand for a few minutes, it becomes *flat*: this is owing to its having lost all its carbonic acid.—The cost of these powders is about 6*d*. a-dozen sets.

TO BREW A GALLON OF GINGER BEER.—Two pounds of the best refined lump sugar, a couple of fresh lemons finely sliced, two ounces of the best fresh powdered ginger, and a desert spoonful of cream of tartar, are to be put into a gallon of fine soft water. Let the whole simmer for an hour over a gentle fire, taking care not to let it boil. Pour off the clear liquor, let it stand till cool, add a table spoonful of porter yeast, milk warm, let the whole repose 24 hours, scum off the top, strain the liquor through a flannel bag, and bottle it up. N.B. The ginger beer commonly met with, contains only half the above ingredients to the same quantity of water. By varying the proportions of the ingredients, the beer can be made hotter, sweeter, or more acidulous, according to the brewer's taste.

METHOD OF PREPARING SODA WATER.—Soda water is prepared (from powders) precisely in the same manner as ginger beer, (see preceding exp.) except that, instead of the two powders there mentioned, the two following are used: for one glass, 30 grains of carbonate of Soda; for the other glass, 25 grains of tartaric or citric acid.

LEMONADE.—Mix one part of citric acid with six parts of finely-pounded loaf-sugar: a very fine dry lemonade is thus prepared, which may be preserved for any length of time. The quantity of this mixture necessary to be put into a glass of water to make a pleasant drink, must be regulated by the taste of the person using it.

INSTANTANEOUS PRODUCTION OF CURDS AND WHEY FROM MILK.—A very ready and elegant mode of procuring curds, and also a pleasant acidulous whey, is, by adding to a glassful of milk a small quantity of the solution of citric acid, taking care not to add too much; an experiment or two will readily show the quantity necessary to effect the purpose.

READY METHOD OF ASCERTAINING THE PROPORTION OF ALCOHOL IN WINES, BEER, CIDER, AND OTHER SPIRITUOUS LIQUORS.—To 100 parts in volume of the liquid to be tried, add 12 parts of solution of sub-acetate of lead, (prepared as directed below,) a precipitation ensues; which, by a slight agitation, is rendered general. On filtering, a colourless liquid, containing the alcohol, is procured. By mixing with this dry and warm carbonate of potash, (calcined pearl-ash,) as long as it is dissolved, we separate the water from the alcohol. The latter is seen floating above in a well-marked stratum; the quantity of which can be estimated at once, if the operation is performed in a graduated tube.

Preparation of the solution of sub-acetate of lead.—Boil 15 parts of pulverised and calcined litharge, with 10 of acetate of lead, in 200 of water, for 20 minutes, and concentrate the liquid by slow evaporation to one half; it must be kept in well-corked phials quite full.

PROOF THAT BEER CONTAINS CARBONIC ACID.—Put a small quantity of porter or ale into a retort, and submit it to a gentle distillation. Conduct the gas which issues from the beak of the retort into lime water, or a solution of chloride of calcium. A white precipitate of carbonate of lime will soon be produced in the solution.

EXTRACTION OF SPIRITS OF WINE.—Submit a portion of Edinburgh ale, London porter, or port wine, to distillation in a retort, furnished with a receiver (page 18). When heat is applied, the alcohol soon distils over, and may be known by its inflammability.

Aromatic Vinegar.—Mix acetate of potash with a little camphor, essence of lemon, or oil of cloves; add a small quantity of oil of vitriol, and submit the mixture to distillation. The product, received in a cooled glass vessel, is aromatic vinegar.

Preston Salts.—Consist of carbonate of ammonia scented with oil of cloves, cinnamon, lemon, &c.

Volatile Oils.—Provide a tin saucepan, with a wire trellis platform supported about two inches from the bottom of the pan, and with a lid made like the top of a still, having a descending neck like that of a retort. Put water at the bottom of the saucepan, and upon the platform the plant from which you wish to extract the oil, such as rose leaves, &c. Fix on the top, and make the water boil. The steam will extract the oil from the vegetable, and run out of the end of the tube, if cooled properly, in a liquid state. After settling in a proper vessel, the oil will rise to the surface of the water.

Test for the Purity of Volatile Oils.—Many of the volatile oils being produced in small quantity, are high priced. There is, therefore, some temptation to adulterate them with fixed oils, to increase the quantity. To detect the fraud, let a single drop of the suspected oil fall on clean paper, and expose it to a gentle heat. If the oil be pure, the whole will be evaporated, and no trace will remain in the paper; but if it has been mixed with a fixed oil, a greasy spot remains behind.

To make Spanish Soap.—Take of carbonate of soda two parts, of olive oil two parts, of water one part. Heat the mixture in a pan over the fire.

To make Shaving Liquid, or Essence Royale pour faire la Barbe.—Dissolve Spanish soap in spirits of wine, till it produces a somewhat gelatinous but transparent liquid.

Transparent Soap.—Slowly and carefully evaporate the shaving liquid produced by dissolving Spanish soap in spirits of wine. It leaves a beautiful solid mass of pure soap.

Tooth Powder.—Finely powdered charcoal forms an excellent tooth powder; it cleanses the mouth both mechanically and chemically; but, as it is dusty, and not easily miscible with water when alone, it may, on this account, be mixed with an equal weight of prepared chalk, and, if requisite, scented with a drop or two of oil of cloves.

CHEAP SCOURING DROPS.—Take a wine glassful of rectified oil of turpentine, and half a tea spoonful of essential oil of lemons. Mix them together, and preserve the liquid in a well-stopped phial.

SOLUTION OF SOAP IN ALCOHOL is employed to ascertain the comparative hardness of waters. With distilled water it may be mixed, without any change ensuing; but, if added to a hard water, it produces a milkiness, more considerable as the water is less pure; and from the degree of this milkiness, an experienced eye will derive a tolerable indication of the quality of the water. This effect is owing to the alcali quitting the oil whenever there is present in a water any substance with which the alcali has a stronger tendency to combine. On this account, all uncombined acids, and all salts, except those of alcalies, decompose soap, and occasion that property in waters which is termed hardness.

TO DISCOVER IF BREAD IS ADULTERATED WITH ALUM.—The bread must be soaked in water, and to the water in which it has been soaked, a little of any test for sulphuric acid must be added. Upon which, if any alum be present, the liquid will be milky; but, if the bread be pure, the liquid will remain limpid.

TO DETERMINE WHETHER WHEAT, FLOUR, OR BREAD BE ADULTERATED WITH CHALK.—1. Mix with the flour to be tried, a little sulphuric acid; if chalk or whiting be present, an effervescence (arising from the discharge of the carbonic acid of the chalk) will take place; but, if the flour be pure, no effervescence is produced. 2. Pour boiling water on some slices of bread, and then pour into the water a little sulphuric acid: if there be any chalk in the bread, an effervescence ensues.

TO DETECT COPPER IN PICKLES OR GREEN TEA.—Put a few leaves of the tea, or some of the pickles cut small, into a phial, with two or three drachms of liquid ammonia, diluted with one-half the quantity of water.—Shake the phial: if the most minute portion of copper be present, the liquid will assume a fine blue colour.

TEST FOR JELLY.—Let a grain of isinglass, glue, or any other gelatinous matter, be dissolved in a gobletful of water, and let a few drops of tincture of galls be added to the solution: the immediate product will be an abundant flocculent precipitate. This precipitate is a compound of the *tan* of the gall, and the pure *gelatin* of the jelly.

INGREDIENTS OF TEA.—1. Put an infusion of green or black tea into a test tube, and add a solution of isinglass. The *gelatin* contained in the test, combines with the *tannin* of the tea, and produces a tawny coloured precipitate, which is finely divided *leather*.—2. To another portion of the infusion of tea, add a solution of sulphate of iron. A black colour will be produced, in consequence of the formation of *ink* by the iron of the test with the *gallic acid* of the tea.

COMBUSTION OF SUGAR.—Melt a little powdered loaf sugar in a ladle, and ignite it: a fine jet of flame is produced.

TO DISTINGUISH A SOLUTION OF EPSOM SALT FROM A SOLUTION OF OXALIC ACID.—1. Taste the solution: Epsom salt is bitter; oxalic acid extremely sour.—2. Pour a little tincture of litmus into the solution: if Epsom salt be present, the blue colour will remain unchanged; if oxalic acid be present, the blue will be turned to red.—3. Tincture of cabbage, or any other vegetable infusion, or a slip of litmus test-paper, are all acted upon by the acid, (which changes their colours) but not by the salt.—4. Oxalic acid, when dropped into water, makes a *crackling noise*, which Epsom salt does not.

JEWELLER'S ROUGE PLATE POWDER.—Finely-powdered venetian red, or red oxide of iron. Prepared by adding a solution of pearl ashes to a solution of green vitriol, and drying and igniting the precipitate.

DIAMOND CEMENT.—Dissolve five or six pieces of gum mastic, as large as peas, in the smallest possible quantity of alcohol. Mix this liquid with two ounces of a strong solution of isinglass, (made by softening and dissolving isinglass in boiling brandy or rum to saturation) having previously incorporated the two ounces of isinglass solution with two or three small pieces of galbanum or gum ammoniac, by trituration. The mixture is to be preserved in a well closed bottle, and is to be gently heated at the moment when you are going to use it.

UNIVERSAL CEMENT.—Curdle skim milk, press out the whey, break the curd in small pieces, dry it, and grind it in a coffee mill. Take ten ounces of dry curd, one ounce of fresh burnt quicklime, and two scruples of camphor. Mix the whole intimately, and preserve it in small wide-mouthed bottles, closely corked. When it is to be used, mix it with a little water, and apply it immediately.

CHEMICAL CURIOSITIES.

Chemical Combination and Decomposition.—1. Shake together, in a small phial, a quarter of an ounce of olive oil, and the same quantity of water; then allow the mixture to settle, upon which the oil and water will separate. Now, add to the mixture a drachm of a solution of an alcali, either carbonate of potash or of soda, and shake the phial again. Upon this, these three bodies will form a substance resembling thick cream.—Oil does not combine with water; but combines readily with alcalies, and forms *soap*.—The cream-like appearance of the above mixture, is occasioned by the diffusion of the soap that is formed, through the water.

2. To the product of the preceding experiment, add a little diluted sulphuric acid. The soap will instantly be decomposed. For the acid combines with the alcali, and forms a *salt* which is dissolved in the water: while the liberated oil rises to the surface of the mixture.

Curious Examples of Chemical Decompositions.—1. Take a solution of sulphate of iron, and a little infusion of galls, both diluted till colourless, pour them together—the mixture will be black.—The sulphate of iron is decomposed, and gallate of iron produced.

2. Into the black liquor, which is the product of the preceding experiment, pour a little diluted muriatic acid: the mixture will immediately become colourless.—In this experiment we form chloride of iron, which gives a colourless solution.

3. To the limpid liquid produced by the last experiment, add a solution of caustic potash, which is colourless: the mixture will again become black.—Here the chlorine of the muriatic acid quits the iron to unite with the potassium of the potash, and the disengaged iron is caught up by the

gallic acid which remains in the solution, to re-produce the black gallate of iron.

4. Immerse a piece of gold—a coin will do—in a glass of mercury. After a few seconds take it out: it will be apparently transformed into silver. Drop the silver-looking metal into a little diluted nitric acid: upon taking it out, after a little while, it will be found to have resumed its natural appearance.—*Rationale.* Mercury combines with gold, so that amalgamation takes place whenever the two metals are placed in contact. The coin, in the above case, becomes cased in an amalgam of gold. The nitric acid, into which the metal is afterwards put, dissolves the mercury, but does not act upon the gold.

5. Take an ounce of mercury and an ounce of sulphur; melt them together in a crucible, stirring the mass continually; pour the mixture on a piece of marble or glass, greased and warmed. The substance thus obtained is sulphuret of mercury, which you may sublime, and thus form the beautiful pigment called vermilion.

6. Take equal parts of muriate of ammonia and lime, (newly burnt,) these bodies are inodorous: triturate them in a mortar; upon this, a very pungent smell is immediately produced. If the operation is performed quickly, and the mixture put in a bottle, well closed, it serves as a smelling bottle for a long time.—*Rationale.* The chlorine, which is a constituent of the muriate of ammonia, combines with the calcium of the lime, and yields up the ammonia in the state of gas. It is this ammoniacal gas which has the pungent smell.

EXPULSION OF VOLATILE ACIDS BY OTHERS THAT ARE LESS VOLATILE.—*Carbonic Acid by Acetic Acid.* Put a solution of carbonate of potash into a tumbler, and pour over it a little acetic acid. The carbonic acid will be expelled with effervescences, and acetate of potash will remain.

Acetic Acid by Muriatic Acid.—Into the newly-formed acetate of potash, pour muriatic acid as long as acetic acid (known by the smell) continues to be evolved. The new compound, chloride of potassium, is a salt that may be crystallised.

Muriatic Acid by Nitric Acid.—Into the solution of chloride of potassium, pour nitric acid; the muriatic acid, which has a very pungent smell, will be expelled; and nitrate of potash will remain.

Nitric Acid by Sulphuric Acid.—Pour sulphuric acid into the solution of nitrate of potash, obtained in the last experiment. A solution of sulphate of potash will result.

If this series of experiments was performed in a retort, and the gaseous acids were discharged thence into proper receivers, and examined by tests, in the manner hereafter described, the results would be far more satisfactory.

NEUTRALISATION.—1. Examine the relations of acid and alcaline solutions towards vegetable colours, employing both test papers and solutions. See pages 23, 122, 276. Notice what very slight portions of acid or alcali affect the colour of some of the tests.

2. Ignite isinglass or some other animal substance in a glass tube, and test the vapours given out at the mouth of the tube by a slip of moistened turmeric paper, for ammonia.

3. Compare the effects of boracic acid and other acids on turmeric and litmus paper.

4. Neutralise a solution of carbonate of potash by adding sulphuric acid, testing the solution with litmus paper as you proceed.

ASTONISHING DIVISIBILITY OF MATTER BY CHEMICAL MEANS.—Take one grain of carmine, and a measured drachm of liquid ammonia; make a solution by grinding them together in a mortar. Add the mixture to 75 pounds of water, and stir the whole together. Every part of the water becomes coloured, and, consequently, each grain of water is placed in juxtaposition with the *five hundred and twenty-five thousandth part of a grain* of carmine. As the hundredth part of a grain of this coloured water is a sensible quantity, the grain of carmine must be evidently capable of division into more than fifty-two millions of solid particles, possessed of the original colour of the mass.

DOUBLE DECOMPOSITION OF TWO SALTS.—Prepare a solution of carbonate of soda, and a solution of chloride of barium, (both transparent liquors)—mix them together in a test glass; this done, a very heavy white powder will be thrown down immediately. Here, a mutual decomposition, and formation of two new salts, carbonate of barytes, and chloride of sodium, take place. The former is precipitated:

whilst the latter remains in solution, and may be crystallised into common *table-salt.*

SOLUTIONS.—1. Weigh out an equal quantity of crystallised sulphate of potash, sugar, sulphate of lime, and sulphate of soda. Put each into the same quantity of water, and observe the difference in the solubility of these compounds.

2. Make a mixture of starch, sand, sugar, and chalk. Put this into cold water, agitate the mixture, and filter. The cold liquor will contain the sugar. Boil the solid matter in fresh water, in a porcelain capsule. The hot water will dissolve the starch, which may be washed away. After filtration, add muriatic acid to the solid mass, to dissolve and remove the chalk. The sand will then remain alone.

3. Boil gum mastic in alcohol, in a glass tube, closing the mouth of the tube with the finger, to produce an elevated temperature. The resulting solution, largely diluted with alcohol, is a good wash to fix pencil or chalk drawings.

4. Dissolve a grain of copper in six drops of nitric acid, using a tube of the following form. Observe the effervescence that is produced; the production of red gas just above the liquor, the change of the liquor to green, the heat which is produced, the peculiar smell that is disengaged. In one minute the copper will be all dissolved, the liquor remaining green. Blow air into the tube by a smaller tube held in the mouth. This expels the red gas, and turns the green liquor blue. Alternately shake the tube and blow air into it, until the green colour and red gas no more return. The smell goes away with the gas. Look *into* the tube, and not *across* it, to see the colour of the liquor and gas. Boil it next over a candle. White fumes of nitric acid go away. When the liquor gets thick and pasty, allow it to cool. It will form a mass of blue crystals, proceeding like rays from a centre. This is

nitrate of copper. Apply heat; the crystals then melt, get drier, and stick about the sides of the glass as a hard cake. The salt now decomposes, and a strong smell of nitric acid is disengaged. When the bulb is cold, half fill it with water. Part of the hard matter dissolves, producing a blue solution of nitrate of copper; part remains undissolved as a bluish-green powder. This is a nitrate with excess of base, which is insoluble in water. Add a single drop of nitric acid, and the whole will dissolve. With the resulting solution, you can apply the different tests for copper.

5. Make a solution of chromate of potash in a tube, add a little oil of vitriol and alcohol, and boil the mixture. The original yellow solution gives a precipitate of green hydrate of chromium. Filter the solution, and ignite the hydrate in a tobacco-pipe held over a spirit lamp or gas light. It then produces fine green oxide of chromium.

SUBLIMATION.—1. Spread a small quantity of grossly-powdered gum-benzoin on the bottom of a Wedgewood's-ware basin, invert over it a glass tumbler, and apply to it a gentle heat by means of the lamp-furnace: the gum will melt, and dense fumes will immediately rise from it and deposit themselves in beautiful silky crystals (which are benzoic acid) on the sides of the glass.

2. Take a large glass jar, containing at its top a sprig of rosemary or some such shrub, and invert it over a flat thick piece of heated iron on which coarse powder of gum-benzoin has just been spread—then, the benzoic acid which arises, as in the preceding experiment, will be deposited on the branches of the shrub, producing a singular and beautiful representation of hoar frost.

3. Sulphur may be distilled by sublimation, using a retort with a very short neck joined to a receiver.

4. Powdered indigo, very gently heated between two watch glasses or tin capsules, sublimes in very splendid copper-coloured crystals.

5. Take two parts of marble, and one part of muriate of ammonia. Pulverise them separately, and mix the whole intimately together. Put the mixture into a Florence

flask, and put the neck of the flask through a cork into a receiver or large tube. Heat the flask by a lamp, and cool the receiver by wet paper. Carbonate of ammonia will sublime and condense in the solid state in the receiver.

DISTILLATION.—Distil half a pint of water as directed page 62, and preserve it for use.

Distil a small quantity of red wine in a little retort, page 20, and examine the alcohol produced.

CRYSTALLISATION.—Dissolve a quantity of saltpetre in water with the aid of heat. Set the solution aside in a deep basin to crystallise. Pick out the best crystals, and preserve them as specimens. Evaporate the liquor again, to furnish a second crop of crystals.

In the same manner, prepare and crystallise solutions of sulphate of iron, sulphate of copper, sulphate of soda, sulphate of magnesia, and alum.

TO FORM BEAUTIFUL CRYSTALS OF IODINE.—Dissolve iodine in boiling alcohol, and let the solution cool. Splendid crystals, an inch and a half long, are produced in a few minutes.

ALUM BASKETS.—Form a small basket about the size of the hand, of iron wire or split willow; then take some cotton, such as ladies use for running into flounces; untwist it, and wind it round every limb of the basket. Boil a pound of alum in a quart of water, or quantities in that proportion: stir the mixture while boiling until the alum is completely dissolved. Pour the solution into a deep pan or other convenient vessel, and suspend the basket in the liquor so that no part of the basket shall touch the vessel, or be exposed to the air. Let the whole remain perfectly at rest for twenty-four hours. When you then remove the basket, the alum will be found very prettily crystallised over all the limbs of the cottoned frame.

EVERY SALT HAS A CERTAIN DETERMINATE FIGURE WHICH IT ASSUMES UPON CRYSTALLISATION.—*Process* 1. Dissolve in separate portions of boiling water, equal weights of sulphate of copper and nitrate of potash; pour them together while hot, into an evaporating dish, drive off by heat a little of the water, and then suffer the mixture to cool, when the salts will shoot—the sulphate of copper into *blue* crystals, the nitrate of potash into *white* ones—precisely similar to what they were before they were dissolved.—*Process* 2.

Treat, in the same manner, sulphate of iron and chloride of sodium: the former salt is separated from the solution in *green* crystals by alternate evaporation and cooling; the latter salt can only be obtained in *white* crystals by converting all the water into steam.—*Process* 3. Dissolve a quarter of an oz. of each of the following salts in a small quantity of water, in separate glasses,—sulphates of magnesia, iron, copper, soda, alumina and potash (alum). Pour the whole into the Wedgewood's-ware basin, and slowly evaporate a portion of the water. When the liquid has acquired its proper degree of density (the student will be taught by practice to know when this is the case,) it must be set by to cool—when every salt will crystallise in its own peculiar manner; having the identical colour, form, taste, and other properties by which it was distinguished, previous to its solution: the mixture of the different crystallised salts having a most pleasing, singular, and beautiful appearance.

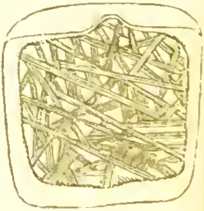
TO OBTAIN LARGE AND BEAUTIFUL ARTIFICIAL CRYSTALS.—This operation requires considerable address, and much patient attention; it is as follows: a solution of the salt to be crystallised is to be slowly evaporated to such a consistence that it shall crystallise upon cooling, which may be known by letting a drop of it fall on a plate of glass. When it is in this state, set it by; and when it is cold, pour into a flat-bottomed vessel the liquid part of the solution off the mass of crystals which will be formed at the bottom of it. After a few days solitary crystals will be formed, which will gradually increase in size. Pick out the most regular of these, and put them into another flat-bottomed vessel; and pour over them a fresh solution of the salt evaporated till it crystallises on cooling. After this, alter the position of every crystal once a day with a glass rod, so that all the faces of it may be alternately exposed to the liquid; for the face on which the crystal rests never receives any increment. By this process the crystals gradually increase in size. When they are so large that their forms can be easily distinguished, take the best of them, and put each into a vessel separately; add a fresh solution of the salt as before directed; and turn every crystal several times a-day. By this treatment you may obtain them almost of any size you wish. It is necessary to pour off the liquid from the crystals, and add fresh liquid in its place, very frequently; for the solution, after depositing a certain portion of its salts, becomes weakened, and then attacks the crystals—rounding off their angles in the first place, as an attentive observer may perceive, and infallibly destroying them, unless renewed.—The student may endeavour to form a regular crystal of *alum* thus, to exercise his dexterity.

To make Cinders, or little Wicker-figures, appear as if they were Crystallised.—Saturate water *kept boiling*, with alum; then set the solution in a cool place, suspending in it, by a hair, or fine silk thread, a cinder, a sprig of a plant, or any other trifle; as the solution cools, a beautiful crystallisation of the salt takes place upon the cinder, &c. which are made to resemble specimens of mineralogical spars.

Pleasing Example of Crystallisation by Fusion.—Take common red litharge, pour over and stir well with it one-third of its weight of strong muriatic acid. Let the mixture become dry, then melt it in a crucible, and pour it into a metallic vessel while in a state of fusion. The mass when cool will be of a beautiful yellow colour, and when broken will exhibit the most regular crystallisation that can be conceived.

To Melt a piece of Metal in a Nutshell.—Take three parts of nitre, (freed from water of crystallisation by exposure to heat,) one part of sulphur, and one of very fine dry saw dust—mingle the whole intimately together. This is called the *powder of fusion*, and is a kind of chemical flux. Let a quantity of this be well pressed into a wallnut shell, with a thin piece of copper coiled up in the midst of it, and then set on fire: it will burn rapidly, and the metal will be fused into a round globule, while the shell is only blackened.

To obtain Beautiful transparent yellow crystals of Brimstone.—Melt about a pound of sulphur in a crucible, remove it from the fire, and let it cool till a crust is formed on the surface. Prick a hole in the crust, invert the crucible, and let the residue of the liquid sulphur run out. When the crucible is cold break it to get at the crystals in the interior.



Crystals of sulphur can also be

prepared by dissolving sulphur in hot oil of turpentine, and letting the solution cool.

IMITATIONS OF MEDALS AND SEALS IN SULPHUR.—Melt the sulphur and pour it into water. It then becomes soft and waxy, and can be made to take very exact impressions from medals.

ON TAKING SPECIFIC GRAVITIES.—By the term specific gravity is understood the density (or quantity of matter under a certain bulk) of one body, compared to the density of another. This latter body is assumed as a standard, and the standard to which bodies are generally compared is pure water at the temperature of 60°. In other words, specific gravity is the comparative weights of different sorts of matter. Having found, by a certain process, that a given quantity of water weighs 1000, we employ the same method to ascertain the weight of the same quantity of the metal mercury; we find it to be 13000: thus we have the comparative weights of the same bulk of these two bodies, and we say that the specific gravity of mercury is, to that of water, as 13 to 1. If water at 1000 is assumed as a standard of specific gravities, which, as it has been said, it generally is; then the specific gravity of mercury (given with a reference to the standard) is 13000. The object of finding the specific gravity of bodies, is to distinguish them from each other in one of their most obvious qualities—namely, weight of matter contained in a given space. We proceed to describe the methods by which the specific gravities of different kinds of bodies are obtained.

TO DETERMINE THE SPECIFIC GRAVITY OF A SOLID, it is weighed, first in air, and then in water. To do this, it is necessary to be provided with very accurate scales, to the bottom of one of which is affixed a small hook, to which the substance is fastened by a fine thread, or hair. When the solid, after being weighed in the air, is lowered into the water, it loses of its weight, a quantity precisely equal to the weight of its own bulk of water; and hence, by comparing this weight with its total weight, we find its specific gravity. The rule therefore is, divide the total weight by the *loss* of weight in water, the quotient is the specific gravity. Thus, if a mineral weigh 3 ounces in air, and 2 ounces in water, and the *total* weight be divided by the *loss*, which is 1, the quotient, or specific gravity of that mineral, will be 3.

A VERY READY WAY TO DETERMINE THE SPECIFIC GRAVITY OF SOLIDS, is to fill a phial with water, and note the weight of the whole accurately in grains. Then weigh 100 grains of the mineral or other substance to be examined, and drop it gradually into the phial of water. The difference of weight of the phial with its contents now, and when it was filled with water only, will give the specific gravity of the matter under consideration. For example, if the bottle weighs 50 grains more than it did when filled with water only, it shows that 100 grains of the mineral displace only 50 grains of water, and consequently that its specific gravity is 2000, or twice that of water. The kind of phial which may be advantageously used for experiments of this kind, is called A SPECIFIC-GRAVITY BOTTLE. It is a little globular bottle with a flat bottom. It has a glass-ground stopple, with a small hole through it. When the bottle is filled with water, or any other liquid, and the stopple put in its place, the superfluous water escapes through the hole, and the bottle remains quite full, without any portion of air. A weight to counterpoise the bottle must be obtained, made of brass or lead.

TO DETERMINE WITH READINESS THE SPECIFIC GRAVITY OF A LIQUID.—We use for this the *specific gravity bottle.* This, when filled with water, contains 500, 1000, or any even number of grains. This bottle is filled with the liquid, the specific gravity of which is required, and then weighed with its contents: the result, deducting the weight of the bottle, is the weight of the liquid under examination, compared to the weight of water. If, for instance, the bottle holds 1000 grains of water, and 1850 grains of sulphuric acid, then the specific gravity of the latter, is to that of the former, as 1850 is to 1000.

In taking the specific gravities of bodies, attention should always be paid to their temperature; because the specific gravity of a body when heated, is much less than the specific gravity of the same body, in a cold state.

METALLIC TREES.—Some of the metals, when precipitated in a particular manner from their solutions, crystallise into the appearance of very beautiful trees or plants. These experiments are not only curious and entertaining, but very simple; and, therefore, I subjoin the processes for making them.

FORMATION OF THE LEAD TREE.—Dissolve two drachms of acetate of lead (sugar of lead) in six ounces of rain water, previously boiled; filter the solution; and pour it into a clean wide phial. Then suspend a thin roll or a granule of zinc, by a thread or wire fastened to the cork of the phial, in the middle of the solution, and place the phial where it will not be disturbed. After a few hours, the lead (which is disoxidized by the zinc) is precipitated on the zinc in the shape of scales or leaves, which have a very brilliant appearance, and form a kind of metallic shrubbery. If the phial remains undisturbed, the lead tree preserves its brilliant appearance for a long time.

FORMATION OF THE SILVER TREE.—Mix one part of a saturated solution of nitrate of silver, with twenty parts of distilled water, and pour the mixture upon two parts of metallic mercury in a phial. After some time (the phial being left standing quietly) it branches, and a figure of a tree formed of brilliant silver will appear to grow from the mercury in a very beautiful manner.

EASY PRODUCTION OF SILVER SHRUBBERY.—Bend a piece of copper wire into the shape of a tree, (but *flat*), or any figure you choose, and lay it upon a piece of glass or slate, over which you have previously spread a few drops of nitrate of silver. In a few hours, the copper will be covered by brilliant ramifications of silver.—*Process* 2. Drop a little solution of nitrate of silver upon a clean plate of copper; in a short time, a very elegant metallic vegetation will be observed to branch out.

FORMATION OF THE IRON TREE.—Add a saturated solution of sub-carbonate of potash, to a solution of nitrate of iron. The mixture swells up considerably, then sinks to rest, and metallic branches spring out in a very curious manner on the surface of the glass.

INCOMBUSTIBLE MUSLIN.—Soak muslin, or any other fabric in a strong solution of phosphate of ammonia, and afterwards dry it well. If you expose this muslin to the flame of a candle, it becomes charred, but cannot be made to inflame.

You may also render muslin incombustible by dipping it into a solution of boracic acid.

INCOMBUSTIBLE PAPER.—Prepared in the same way as incombustible muslin.

TENACITY OF FUSED BORAX.—If you expose borax in a crucible to a very strong heat, and pour it, when melted, into another vessel, you may take hold of the resulting glass and pull it into strings of many yards in length.

TO SHOW THAT THE ATMOSPHERE CONTAINS WATER, EVEN IN THE DRIEST WEATHER.—1. Expose to the open air, for a few days, a spoonful of dry sub-carbonate of potash, or muriate of lime, spread in a saucer: the salt will attract so much moisture from the air, that it will become liquid.—2. Put a given quantity of strong sulphuric acid into a vessel exposed to the air; at the expiration of twenty-four hours, its weight will be found to have increased one-third.

CAMPHOR.—I. A chip of camphor may be burned while floating on water.

II.—Put some camphor on a metallic plate, over a spirit lamp, and cover it with a glass funnel. The heat will cause the camphor to sublime in a pure state, producing an efflorescent crust.

III.—A little of this sublimed camphor mixed with finely-powdered chlorate of potash, can be inflamed by the contact of sulphuric acid (page 311.)

IV.—If camphor is dissolved in alcohol, and water is added to the clear solution, the camphor ascends and floats in the solid form.

V.—If a small piece of camphor is placed on the surface of water contained in a basin, it immediately begins to move round and round with considerable rapidity. It is necessary that the water be pure, for, if dust or grease be present, the camphor will not move, or, if, while its rotatory motion is proceeding, a single drop of grease be let fall into the water, the camphor will instantly start away from it to the side of the basin, and its motion will be put a stop to.—Nothing satisfactory has yet been advanced in explanation of this phenomenon.

TO MAKE BEAUTIFUL GOLDEN FIGURES UPON SILK.—Dilute a solution of chloride of gold with thrice its quantity of water, and with the solution paint flowers, or shrubs, on a piece of white silk, then expose the silk (kept moist by being wetted with pure water) to a current of hydrogen gas, which is to be forced through a pipe, from the vessel containing it. The hydrogen gas will reduce the oxide of gold,—the colour of the paintings will change from yellow to green—and the figures will soon shine with all the splendour of the finest gold. NOTE.—Unless the silk is kept wet, the effect will not be produced.

TO MAKE BEAUTIFUL SILVERY FIGURES UPON SILK.—Immerse a piece of silk in a diluted solution of nitrate of silver, and expose it while *wet* to a current of hydrogen gas (as described in the preceding experiment) the silver will quickly be reduced; various colours,—blue, purple, red, orange, yellow,—accompany the reduction, and at last the threads of the silk appear like silver wire.

TO MAKE A PIECE OF CHARCOAL APPEAR AS THOUGH IT WERE COATED WITH GOLD.—Dilute a saturated solution of chloride of gold with five times its bulk of water, place a thin slip of fresh-burned charcoal into it, and apply heat, gradually increasing it till the solution gently boils.—The heat will make the charcoal precipitate the metal on the charcoal, in the form of brilliant spangles.

TO GIVE A PIECE OF CHARCOAL A RICH COAT OF SILVER.—Lay a crystal of nitrate of silver upon a piece of burning charcoal,—the metallic salt will deflagrate, and throw out the most beautiful scintillations that can be imagined. The silver is reduced, and, in the end, produces upon the charcoal, an appearance very brilliant.

TO CONVERT IRON (APPARENTLY) INTO COPPER.—Dip a piece of polished iron (as the blade of a knife) into a solution either of nitrate or sulphate of copper: it will assume the appearance of a piece of pure copper.

TO ENGRAVE FIGURES ON GLASS.—Cover one side of a flat piece of glass, after having made it perfectly clean, with bees' wax, and trace figures upon it with a needle, taking care that every stroke cuts completely through the wax. Next, make a border of wax all round the glass, to prevent any liquid when poured on from running off. Now, take some finely-powdered fluor spar; strew it evenly over the glass plate, upon the waxed side, and then gently pour upon it, so as not to displace the powder, as much sulphuric acid, diluted with thrice its weight of water, as is sufficient to cover the powdered fluor spar. Let every thing remain in this state for three hours, then remove the mixture, and clean the glass by washing it with oil of turpentine: the figures which were traced through the wax will be found engraven on the glass; while the parts which the wax covered, will be uncorroded.—*Rationale.* The fluoride of calcium is decomposed by the sulphuric acid, and sulphate of lime is formed. The fluoric acid disengaged in the gaseous state, corrodes the glass.

CHEMICAL TESTS.

THE method of applying these tests is explained in the article on "Testing," at page 24. The tests named in the present section are such as are employed most frequently, and the metals and salts instanced under each head, are such as are commonly presented for examination. Each test upon being added to the solution of the salt which is to be analysed, either effects no change, or produces a precipitate, and the precipitate is either white or coloured. The constituents of salts are acted upon differently by different tests, and are consequently arranged in different sections, under the names of the different tests. It is from a comparison of the effects produced by a variety of tests applied to a given saline solution, that an opinion is formed as to the nature of the salt which the solution contains. For further particulars on this subject, see ROSE's "*Manual of Analytical Chemistry*," London, 1831.

LIQUID AMMONIA.

WHITE PRECIPITATE:—Magnesia, if the solution is neutral. Alumina. Manganese. Zinc, soluble in excess. Cadmium, soluble in excess. Iron, protosalts, turns brown. Lead. Tin. Bismuth. Mercury, persalts. Antimony.

YELLOW PRECIPITATE:—Copper, protosalts; with excess, a colourless solution.

GREY PRECIPITATE:—Mercury, protosalts, from very acid solutions.

GREENISH-BLUE PRECIPITATE:—Cobalt; with excess, forms a brown solution. Copper, deutoxide; with excess, a blue solution.

APPLE-GREEN PRECIPITATE:—Nickel; with excess, a violet solution.

GREEN PRECIPITATE:—Chromium.

BROWN PRECIPITATE:—Manganese, deutosalts. Iron, persalts. Silver; soluble in excess.

BLACK PRECIPITATE:—Mercury, protosalts.

NO PRECIPITATE:—Potash. Soda. Ammonia. Barytes. Strontian. Lime. Silver, if in a very acid solution. Magnesia, do.

CAUSTIC POTASH.

WHITE PRECIPITATE:—Barytes. Strontian. Lime. Magnesia. Alumina, soluble in excess. Manganese, protosalts. Iron, protosalts. Zinc, soluble in excess. Cadmium. Lead, soluble in excess. Tin, soluble in excess. Bismuth. Antimony, protosalts.

YELLOW PRECIPITATE:—Mercury, persalts, insoluble in excess. Copper, protosalts. Platinum. Gold, reddish.

GREEN PRECIPITATE:—Chromium, soluble in excess. Nickel, apple-green.

BLUE PRECIPITATE:—Copper, deutoxide. Cobalt, changes to green.

DARK-BROWN PRECIPITATE:—Manganese, deutoxide.

BROWN PRECIPITATE:—Iron, persalts. Silver, soluble in ammonia.

BLACK PRECIPITATE:—Mercury, protosalts.

NO PRECIPITATE:—Potash. Soda. Ammonia.

LIQUID SULPHURETTED HYDROGEN.

Added to acidulated solutions of the salts.

NO PRECIPITATE:—Potash. Soda. Ammonia. Barytes. Strontian. Lime. Magnesia. Alumina. Manganese. Zinc. Cobalt. Iron. Nickel.

BLACK PRECIPITATE:—Lead. Bismuth, brownish. Copper, deutoxide, brownish. Silver. Mercury. Gold, brownish. Platinum.

WHITE PRECIPITATE:—Iron, persalts.

DARK-BROWN PRECIPITATE:—Tin, protosalts.

YELLOW PRECIPITATE:—Tin, persalts, pale. Cadmium. Arseniates; their solutions must be acidified by muriatic acid and boiled with the test.

ORANGE-RED PRECIPITATE:—Antimony, protosalts.

HYDROSULPHURET OF AMMONIA.

The saline solutions must be rendered alcaline by ammonia before the test is applied.

BLACK PRECIPITATE:—Cobalt. Nickel. Iron. Lead. Silver. Mercury.

DARK-BROWN PRECIPITATE:—Tin, protosalts; soluble in excess. Bismuth. Copper. Platinum, soluble in excess.

ORANGE-RED PRECIPITATE:—Antimony, protosalts.

FLESH-RED PRECIPITATE:—Manganese.

GREEN PRECIPITATE:—Chromium.

YELLOW PRECIPITATE:—Cadmium. Tin, persalts; soluble in excess. Arsenites.

WHITE PRECIPITATE:—Zinc. Alumina.

NO PRECIPITATE:—Potash. Soda. Ammonia. Barytes. Strontian. Lime. Magnesia.

CARBONATE OF SODA.

WHITE PRECIPITATE:—Iron, protosalts. The colour of the precipitate changes to green, and finally becomes reddish-brown at the surface. Barytes. Cadmium. Strontian. Lead. Lime. Tin. Magnesia. Bismuth. Alumina. Silver. Manganese, protosalts. Zinc. Antimony.

GREEN PRECIPITATE:—Nickel, apple-green. Iron, protoxide; the colour is first white, then green, and finally reddish-brown. Chromium, protosalts. Copper, deutoxide, greenish-blue.

PALE YELLOW PRECIPITATE:—Copper, protosalts. Mercury, protosalts; with excess, black.

RED PRECIPITATE:—Cobalt, rose red. Gold, reddish yellow.

BROWN PRECIPITATE:—Iron, protosalts, first white, then changes to green and brown. Manganese, deutoxide. Mercury, persalts.

NO PRECIPITATE:—Potash. Soda. Ammonia.

CARBONATE OF AMMONIA.

WHITE PRECIPITATE:—Barytes. Strontian. Lime. Alumina. Manganese, protosalts. Iron, protosalts. Zinc. Cadmium. Lead. Tin. Bismuth. Mercury, persalts. Silver. Antimony, protosalts.

YELLOW PRECIPITATE:—Copper, protosalts. Mercury, protosalts. Platinum. Gold, reddish colour.

GREEN PRECIPITATE:—Iron, if the solution contains both protosalts and persalts. Nickel, apple-green. Chromium. Copper, deutoxide.

ROSE-RED PRECIPITATE:—Cobalt.

BROWN PRECIPITATE:—Manganese, deutoxide. Iron, persalts.

NO PRECIPITATE:—Potash. Soda. Ammonia. Magnesia.

CARBONATE OF POTASH.

WHITE PRECIPITATE :—Iron, protoxide. The colour of the precipitate changes to green, and subsequently to reddish-brown at the surface. Barytes. Strontian. Lime. Magnesia. Alumina. Manganese, protosalts. Zinc Cadmium. Lead. Bismuth. Silver. Tin. Antimony.

GREEN PRECIPITATE :—Nickel, apple-green. Iron, protoxide. The colour is first white, then green, finally reddish-brown. Chromium, the precipitate turns blue.

BLUE PRECIPITATE :—Copper, deutoxide, black if boiled.

YELLOW PRECIPITATE :—Mercury, protosalts; black if boiled. Platinum, chloride.

RED PRECIPITATE :—Cobalt.

BROWN PRECIPITATE :—Iron, protoxide. The colour is first white, then green, finally reddish-brown. Manganese, deutoxide. Mercury, persalts.

NO PRECIPITATE :—Potash. Soda. Ammonia.

PRUSSIATE OF POTASH.

NO PRECIPITATE :—Potash. Soda. Ammonia. Barytes. Strontian. Lime. Magnesia. Alumina. Chromium. Gold. Antimony.

WHITE PRECIPITATE :—Manganese, protosalts, or pale red. Iron, protosalts. Zinc. Cadmium. Lead. Tin. Copper, protosalts. Mercury. Silver.

YELLOW PRECIPITATE :—Bismuth. Platinum.

GREEN PRECIPITATE :—Manganese, deutoxide, greyish. Cobalt, bluish. Nickel, pale.

BLUE PRECIPITATE :—Iron, persalts.

BROWN PRECIPITATE :—Copper, deutoxide.

TINCTURE OF GALLS.

NO PRECIPITATE :—Potash. Soda. Ammonia. Barytes. Strontian. Lime. Magnesia. Alumina. Manganese Zinc. Cadmium. Platinum.

PURPLE PRECIPITATE :—Iron, protosalts.

BLUISH-BLACK PRECIPITATE :—Iron, persalts.

YELLOW PRECIPITATE :—Cobalt. Lead. Tin. Bismuth. Mercury. Antimony. Cadmium, (from weak acids.)

WHITE PRECIPITATE :—Nickel, dirty colour.

BROWN PRECIPITATE :—Chromium. Silver. Gold. Copper.

CHLORIDE OF BARIUM.

NO PRECIPITATE :—Chlorates. Nitrates. Chlorides. Iodides. Sulphurets.
WHITE PRECIPITATE :—Iodates. Sulphates. Phosphates. Borates. Oxalates. Carbonates. Fluorides.
YELLOW PRECIPITATE :—Chromate.

NITRATE OF SILVER.

NO PRECIPITATE :—Chlorates. Nitrates. Sulphates, except in concentrated solutions.
WHITE PRECIPITATE :—Iodides. Borates. Oxalates. Carbonates. Chlorides. Fluorides.
YELLOW PRECIPITATE :—Phosphates. Iodides.
BLACK PRECIPITATE :—Sulphurets.
RED PRECIPITATE :—Chromates.

PROTONITRATE OF MERCURY.

NO PRECIPITRATE :—Chlorates. Nitrates.
WHITE PRECIPITATE :—Iodates. Sulphates. Phosphates. Oxalates. Chlorides. Fluorides.
PALE YELLOW PRECIPITATE :—Borates. Carbonates. Iodides.
BLACK PRECIPITATE :—Sulphurets.
RED PRECIPITATE :—Chromates.

ACETATE OF LEAD.

NO PRECIPITATE :—Chlorates. Nitrates.
WHITE PRECIPITATE :—Iodates. Sulphates. Phosphates. Borates. Oxalates. Carbonates. Chlorides. Fluorides.
YELLOW PRECIPITATE :—Chromates.
ORANGE PRECIPITATE :—Iodides.
BLACK PRECIPITATE :—Sulphurets.

NITRATE OF LIME.

NO PRECIPITATE :—Chlorides. Chlorates. Iodides. Iodates. Nitrates. Sulphurets.
WHITE PRECIPITATE :—Sulphates, soluble in a large quantity of water. Phosphates, soluble in sal ammoniac. Borates, soluble in water. Oxalates, soluble in nitric acid, but not in water. Carbonates, soluble in nitric acid.

FINIS.